THE GEOLOGICAL

AND

NATURAL HISTORY SURVEY

OF

MINNESOTA.

THE SEVENTEENTH ANNUAL REPORT.

FOR THE YEAR 1888.

N. H. WINCHELL,

STATE GEOLOGIST.

ST. PAUL, MINN.:
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I. C. Russell

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ADDRESS.

THE UNIVERSITY OF MINNESOTA,
MINNEAPOLIS, March 31, 1889.

To the President of the University,

DEAR SIR: I have to communicate again an annual report on the progress of the geological and natural history survey of the state, being the seventeenth in consecutive order. Like the last two, this report pertains almost exclusively to the geology of the northeastern part of the state, and is accompanied by some text illustrations.

Respectfully, your obedient servant,

N. H. WINCHELL,

State geologist and curator of the general museum.

REPORT.

I.

SUMMARY STATEMENT FOR 1888.

The work done in the season of 1888 in consequence of the supplementary aid that was rendered the survey by the special appropriation and law of the Legislature of 1887, as mentioned in the last report, will be found reported elsewhere. The explorations for natural gas carried on within the state, whether by private enterprise or by the aid of the special fund, are detailed, with some considerations relative to the general subject of gas in Minnesota, in Bulletin No. 5. The special field-work which was directed, under the same law, to the discovery and definition of the iron-resources of the northeastern part of the state, will be included in this report. But the whole subject in general of the geology of the iron ores of Minnesota will find place in Bulletin No. 6.

There were two parties in the field during the season. One was occupied, in the first part of the season, in making collections of rock-samples from certain typical crystalline formations in typical localities. This was under the direction of Mr. Uly S. Grant. At the same time some new facts were observed. These, with notes made by him later in the season when occupied more specially with the examination of the iron-ore beds, are gathered together by him in a formal report which accompanies this.

The other party was during the whole season at work on the iron-ore beds. This was under the guidance of my son, Mr. Horace V. Winchell, whose report on his work will also be found accompanying this

The work of the season has added materially to our exact knowledge of the geology of the northeastern part of the state, and particularly to that of the nature and relations of the iron ores of the state. A general presentation of this knowledge, in

a somewhat systematic manner, has been attempted in this report; but it must be admitted, notwithstanding the time spent on the study, and field-observations that have been recorded, there are still some important, and many less important, questions which the survey cannot answer. But with a consciousness that, however exhaustive the research might be made, there would be questions still unsolved, and that there is a general wish for a full and "final" presentation of the geology of that part of the state so far as present knowledge will yield it, and also feeling that the time has been long that the survey has been going on, and that the working span of one man's life cannot be depended on for indefinite extension, I am constrained to say that we shall enter now upon the preparation of the final report covering the northern part of the state. There will be some supplementary examination to be made, but this will be not very costly, and can be executed while the preparation of the report is in progress.

Volume II of the final report was issued in December, 1888. It is a quarto of about 700 pages, forty-two plates and thirty-two figures, of the same style as Vol. I.

A considerable portion of Vol. III is also ready, and the entire volume will be finished at once. It will contain, along with the paleontology of the strata discussed in Vols. I and II, an account of their systematic relations to the geology of the Northwest. There is also, in readiness for publication, a volume devoted to the birds and mammals of the state, prepared by Dr. P. L. Hatch and Prof. C. L. Herrick. These two volumes should be published at once, in style uniform with those already issued.

The monograph of Messrs. Woodward & Thomas on the microscopic fauna of the Cretaceous, which has been in process of preparation several years, has been completed by those gentlemen and has been transmitted for publication. It will form a chapter in Vol. III. Mr. Ulrich's work on the bryozoa of the Trenton was interrupted unfortunately, when it had proceeded so far as the engraving of the plates, eight having been completed and delivered. This was owing to the exhaustion of the fund for publication by the unexpected cost of Vol. II. Dr. Leo Lesquereux's report on the fossil flora of the Cretaceous in Minnesota, with the accompanying plates, is also intended for Vol. III. It is only an act of reasonable justice to a scientific author that his contributions be published as soon as possible. His

rights are not all satisfied by the simple payment of the money involved in his contract to prepare the report. The value of scientific work, especially scientific authorship, is not measured by the manual labor involved in it. So its claims are not satisfied when the material money payment is made. The author expects, and he has a right to demand, that his work shall be published. His researches, so far as they are in new fields, may be covered by later investigators and be announced before his see the light. This reward for scientific authorship, while it cannot be expressed in dollars and cents, and cannot perhaps be included in definite terms in the contract with the author when he undertakes the work of any investigation, yet acts as a powerful stimulant and as a final element in the compensation he reasonably counts upon. He naturally is backward in asserting it; and it is a lamentable fact that credit for some valuable research and some discoveries has been lost to their authors because of the suppression, or at least the tardy publication, of their reports until after others had made the same discoveries and had announced them to the public. In the case of a state survey such delay not only injures the individual but also reflects on the value of the official reports. Wherever scientific facts are first published, there they are forever acknowledged and referred to by future authors. If the state has incurred the cost of an investigation, its chief value is lost if the credit of its discoveries cannot be secured by early publication, and if the same facts are published elsewhere.

The condition of the museum and of the unexamined specimens is about as has been stated in some of the late reports. Not only are the museum halls full to overflowing, but the so-called laboratories of the survey are also full. It has become necessary to deposit the boxes of rock samples in these rooms. All the packing, handling and labeling has been done heretofore in these rooms. Recently, owing to the storage of a large part of the surplus copies of Vols. I and II in these rooms, there has not been room left for doing this work, and it has been transferred to the office, on the second floor of the building.

A record of museum accessions is herewith again reported, the same having been crowded out of the last two reports. Its publication subserves the double purpose of acknowledging donations and of permanence of a record easy to consult in case of desire to find any specimen in the museum, or any information concerning any specimen when once the specimen is in hand. The

method of labeling all specimens collected has been found very safe and permanent. It consists of mixing a solution of common shellac, such as can be got of a druggist, with some coloring material and carefully placing the numbers with a small brush or with a stick, on the specimens, by hand. The shellac, being dissolved in alcohol quickly hardens by the evaporation of the alcohol, and embracing the coloring material in the hardened mass, has the quality of permanence of color and insolubility in water. The upper right hand corner of the specimen is used. In case the natural surface is rough, or if the color of the letter to be attached would be so nearly the same as the rock as to render the designation indistinct, the surface is first colored over in a small rectangular spot with some other color of the same kind of material, and when hardened the number is applied over it. The specimens have been numbered as below.

The regular museum series, such as have been placed on exhibition, whether rock-samples, minerals or fossils, have their numbers in *red*, produced by mixing the shellac with "vermilion red."

The series of N. H. Winchell, mainly crystalline rocks, are marked *blue*, produced by mixing indigo with the dissolved shellac.

The series of A. Winchell, also crystalline, are marked *black*, produced by mixing the shellac with india ink.

The samples collected by H. V. Winchell are marked *pink*, a mixture of vermilion red and white lead with the dissolved shellac.

The samples collected and reported by Mr. U. S. Grant are marked *green*, made by mixing the shellac with paris-green.

The specimens in the archæological collection are marked in *white*, mixture of white lead with the dissolved shellac.

The list of museum accessions herewith reported includes only those marked in *red*. All others are listed in connection with the respective field reports.

II.

REPORT OF N. H. WINCHELL.

The crystalline rocks of Minnesota. General report of progress made in the study of their field relations. Statement of problems yet to be solved.

CONTENTS.

INTRODUCTION. In the course of any investigation that is extended over a number of years, like that of the work of the survey on the crystalline rocks of the state, it is necessary, for an intelligent application of effort, to review the progress made and ascertain as nearly as possible the amount and kind of work that remains. It is one of the characteristics of geological investigation, and particularly of research among the crystalline rocks, that as difficulties disappear, under the reflective scrutiny of the laborer, new problems are presented for solution. In the solution of these more advanced problems the geologist sometimes forgets, in the eagerness of his pursuit, that it is incumbent on him, in the interests of his own work, as well as for the information of others, to render an account of his progress and of his

success in surmounting the difficulties that confronted him at the outset. There are but few investigators, in any branch of science, that have not made mistakes. They may have advanced under illusive guides along devious lines, they may have retreated where they ought to have advanced, or advanced where they should have retreated. They have entertained partial or wrong opinions; but it is evident that no one should be held to these errors that are incident to the process. The final statement only ought to stand for the result of the investigation. This may contravene, or it may modify or totally disprove some of the early views. There is hence a justifiable reluctance on the part of an investigator to publish his results till he is satisfied that he is right, and that the work is finished. In the case of the Minnesota survey, however, like all surveys, it ought to be "finished." That is, its work should be rounded out with a so-called completion; for it is evident that however far the work should be continued there would still remain unsettled questions. It is not within the power of one survey, nor of one generation, to exhaust the possible research that might be applied to the examination of the geology of the crystalline rocks.

For these reasons it is thought best to take an inventory of the survey's work and results in the examination of the crystalline rocks of the state. This will be preliminary only, and the apparent truth, as it may be expressed in this report, may appear different in the light of future discoveries, and the final report on this work may be somewhat different from that which is here foreshadowed.

1. WORK DONE BY THE MINNESOTA SURVEY ON THE CRYSTALLINE ROCKS.

The efforts of the survey have been directed, almost wholly, to the field relations of the terranes. It is evident that all laboratory determinations are subordinate, in their bearing on the general geology, to the labor expended in the field. That which is of first importance is a knowledge of the facts as to superposition, transition, and extent of the various kinds of rocks as they exist, in fact. No fine mineralogical disquisitions, or chemical determinations, or stratigraphical suppositions, or historical reviews of past speculations, can bear the weight of a feather in the balance against the facts of field observation. Dr. M. E Wadsworth has truly said* that the field evidence must in all cases

* Notes on the geology of the iron and copper districts of Lake Superior, p. 74.

be the arbiter and guide to the conclusions of the microscopist in his laboratory work on crystalline rocks, as to their eruptive or sedimentary nature. This supposes that the facts as reported are the actual facts. It is true, however, that from different standpoints the same facts may be reported differently by different observers, or because of a lack of capacity or training in field observation on the part of one or the other.* So far as the work of the survey is concerned, while it would be obviously absurd to assert that no mistakes of field observation have been made, and no incorrect inferences have been arrived at by the field observers, it is no more than the facts of the case will justify to say that the Minnesota survey has devoted more time and accumulated more exact knowledge regarding the field-relations of the crystalline rocks than has any other state survey; and probably has given more time to field work in the crystalline rocks of the Northwest than the United States geological survey. In some instances extensive routes of observation have been gone over more than once for correction or verification. These field observations have been reported in whole or in part, from time to time chronologically in the reports of progress, but their fragmentary parts have not been grouped and presented systematically so as to show the results as they appear in the mind of the writer.

(a) *Early views. State of knowledge when this investigation was begun.*

When the Minnesota survey was begun, in the fall of 1872, there had been but little done on the crystalline rocks of the Northwest. In addition to the desultory and often fragmentary work of the Canadian survey, which should be classed rather as exploration and sketch-mapping, and which had been spread over the Canadian shores of lake Superior as far as to Pigeon river by Mr. Robert Bell, the only published information respecting the older terranes in Minnesota was in the reports of Keating, Allen and Schoolcraft, Shumard, Norwood, Whittlesey and Hall, with some brief notes by Bigsby, on the Lake of the Woods. Douglas Houghton had also visited Grand Portage and some points further west. Eames & Hanchett had also rendered short reports on some features of the northern part of the state.† There had been published also, in 1871, in the *Zeitschrift d. Deutschen*

* Compare Irving's and Wadsworth's different observations on the "Eastern Sandstone," *Copper-bearing rocks of lake Superior*, Monograph No. 5, U. S. Geol. Survey, p. 356, et seq.

† See Vol. I. final report, for some account of these early publications.

geologischen Gesellschaft, a paper by Dr. J. Kloos giving some notes on Minnesota, in which important new observations were recorded. It was two or three years later, however, that this last paper was first known to the writer.* Prof A. Winchell and Prof. R. D. Irving had also made some observations on the geology of the Northwest, particularly in Michigan and Wisconsin. The report of Foster and Whitney on the copper and iron districts of the lake Superior region makes no mention of the geology of Minnesota further than the reported occurrence of one or two minerals on the north shore of lake Superior.

So far as any of this work touches the geology of Minnesota, in the areas of the crystalline rocks, it may be divided into two classes.

1. That which is descriptive of the geographic extent of the crystalline rocks.

2. That which by careful mineralogical determinations discriminates the rock species from each other, or classifies the formations stratigraphically.

In the former may be placed the reports of Keating, Allen, Schoolcraft, Shumard, Eames, Hanchett and Houghton; in the latter are the reports of Norwood, Whittlesey, Hall and Kloos. Norwood's report partakes largely in the character of the first group. Whittlesey's was the result of observations made in company with Norwood, and embraces about the same facts and conclusions. Prof. James Hall's report of a trip from St. Paul to lake Shetek † in 1866, embraces the first reference of any of the crystalline rocks of the state to their supposed stratigraphic equivalents in the eastern states and Canada. He distinctly refers the gneisses at Redwood Falls to the *Laurentian*, and the quartzytes at New Ulm and Pipestone to the *Huronian*, names which had been adopted by the Canadian geologists, though with some ambiguity and overlapping of description, the former in 1854, § and the latter in 1857, § §

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* See transalation of this in the tenth anual report.

† 1866, Trans. Am. Phil. Soc., Philadelphia, p. 329.

§ Geol. Report Can. Survey, 1857, p. 7. The name was used in "Sketch of the Geology of Canada," printed in French in Paris, 1855. This is embraced in "Canada at the Universal Exposition of 1855," by J. C. Tache, a report printed at Toronto, "by order of the Legislative Assembly," 1856. It was first announced in the report of the survey for 1852-53, which, however, was not published till 1854, at Quebec.

§ § In Mr. Murray's reports for 1853, 1854, 1855 and 1856 the terms "Huronian system" and "Laurentian system" are used incidentally, and as headings to chapters; but as these were not offered for publication by Mr. Logan till March, 1857, they cannot be considered as official announcements of those names till the date of their actual publication.

Just prior to the adoption of these terms, expressive of a distributive chronological classification of the terranes of the crystalline rocks, at least all those lying below the Potsdam sandstone, Messrs. Foster and Whitney* had employed the term *Azoic*, after Murchison and Verneuil,† and had divided them mineralogically rather than chronologically, into gneiss, mica and hornblende slate, chlorite, talcose and argillaceous slate, quartz and marble.‡ They considered them an indivisible complex series, whose foldings and metamorphic changes rendered a determination of their original stratigraphic order impossible. This term, with its significance as interpreted by Foster and Whitney, was adopted by Dana in the first and second editions of his Manual of Geology (1862 and 1864), and by the Vermont geologists in 1862 (Geol. of Vermont, Vol. I). It was not till 1874 when the third edition of this manual was issued (by some mistake also called "second" edition), that the terms used by the Canadian geologists were adopted in this work. They are continued in the fourth ("third") edition issued in 1879. Dr. Ebenezer Emmons evidently shared the views of Foster and Whitney. Aside from his opinion that the Huronian of Canada was only a synonym of his Taconic which he insisted was not "Primary," he divided the "primary" rocks into two groups,‖ based on the varying theoretical agency of heat in their production and present condition, viz., *pyro-crystalline* and *pyro-plastic*. In the former, in the main, he embraced granite, gneiss, mica slate, talcose slate, hornblendic and hypersthene rocks, that is to say, speaking broadly, the acid eruptive rocks and their accompanying schists, and in the latter he included the most of the basic eruptives.§

When the Minnesota survey began [1872] the Wisconsin survey, lately completed by Chamberlin, had not yet been instituted,§§ and the Michigan survey, revived in 1869, did not present its first final volume for publication till May 1, 1873. The writer, having been at work in 1870 on the Michigan survey, was, how-

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* Proc. A. A. A. S. 1851, p. 4.

† The Geology of Russia in Europe, Vol. I, p. 10.

‡ Report on the Geology of the lake Superior land district; part II. p. 2. Am. Jour. Sci., (2) xxiii. 305.

‖ Manual of Geology, Second edition, 1860, p. 52.

§ Emmons also regarded some limestones as pyro-crystalline, and he embraces it in both series of that class of rocks. Op. cit. p. 60 et 66.

§§ The law ordering the Wisconsin survey was approved March 18, 1873.

ever, acquainted with the views of the director, Prof. A. Winchell, and of major T. B. Brooks, the geologist of the iron regions, touching the equivalency of the Marquette iron formation to the Huronian of Canada, as subsequently announced in Volume I of that report.

The first volume of the New Hampshire report by Prof. C. H. Hitchcock was issued in 1874, and that devoted to the stratigraphic geology of the Archæan in that state in 1877.

(b) *The problems, therefore, that were then unsolved,* touching the stratigraphy of the Azoic or Archæan, were as follows:

1. Could the Azoic be divided stratigraphically with any probable general applicability?

2. Could the terms Huronian and Laurentian, as employed by the Canadian geologists, find any equivalents in the crystalline rocks of Minnesota?

3. What relation did the Huronian bear to the Cambrian?

4. What relation did the Huronian bear to the Taconic?

5. What relation did the Cambrian bear to the Taconic?

6. What relation did the Animikie bear to the Taconic, the Cambrian and the Huronian?

Correlatively with these problems appeared others, although they did not present themselves so forcibly till some time later, viz.:

7. Could the rocks classed as Laurentian be distinctly shown to be of older date than the Huronian? All of them, or a part of them?

8. Could the Laurentian be subdivided?

9. Is the Laurentian derived from originally sedimentary rock? or from primarily eruptive rock?

10. If originally sedimentary, or if primarily eruptive, why is it mainly an "acid" rock?

(c) *Publications issued since the work began.*

In an appendix is a list of publications that have been issued since 1872, bearing on the geology of the crystalline rock, of the Northwest, so far as the writer has learned of them. It is probably not complete, but certainly embraces everything that has contributed to the subject any important information. To all of these the writer must acknowledge great indebtedness, and to none greater than to the geologists of Michigan and Wisconsin, Maj. T. B. Brooks, Dr. A. Winchell, Prof. R. Pumpelly, Dr. C.

Rominger, Prof. C. E. Wright, A. R. Marvine, Prof. R. D. Irving, Prof. (now President) T. C. Chamberlin, E. T. Sweet, and to Prof. M. E. Wadsworth, now state geologist of Michigan.

(d) *The various annual reports: progress from year to year.*

That there has been some advance in the science of the crystalline rocks in America at large as well as in those of the Northwest, and of Minnesota specifically, since 1872, is evident from a comparison of the problems unsolved in 1872 with those that are presented to the geologist in 1889; and while this advance is mainly due, of course, to the labor of the authors whose works are listed above, some of the steps of this progress may be accredited to the Minnesota survey. Some of these steps, due to a large extent, or wholly, to the Minnesota survey, it will be appropriate here to enumerate. There may be still a difference of opinion among the geologists of the United States and Canada as to what constitutes a step of progress, and as to who should be regarded as its author. But it is the design of the writer to mention only those steps which appear to his judgment to be actual advances, whether they appear so to others or not, and in that he holds no one responsible but himself. As to the responsibility and the credit for these steps, that is decided, as in all similar cases in science, by the dates of the published literature that announces them. The record, therefore, which will here be given, will be that of the progress, mainly, of the writer's own mind and apprehension of what he considers successive advances.

The first annual report, 1872.

The first annual report was made before any time had been allowed for examination of the crystalline rocks of the state by the present survey. Therefore the only design was to express concisely the state of knowledge that then was available, so far as it bore on any classification that might be accepted. The views of Foster and Whitney as expressed in 1851,* grouping the crystalline rocks in the same manner as Murchison and Verneuil, all in one system under the name Azoic,** were cited and their table of stratification was quoted. At the same time the subdivision into Laurentian and Huronian, introduced by Logan and Hunt

**Report on the Geology of the lake Superior land district.* Part II, p. 8. *Proc. A. A. A. S.* 1851, p. 4

** Geology of Russia, Vol. I, p. 10.

of the Canadian survey, though contested by Prof. Whitney, was generally prevalent, and these terms were included in the brief description then published of their extension into Minnesota.

The most important question, however, which was considered in the first report, bearing on the classification of the Laurentian and Huronian, was that pertaining to the *Potsdam sandstone*. The bearing of this discussion, however, upon that classification was not fully apprehended, as its application and significance have been brought to light in some of the later years of the survey. Drs. Owen and Norwood, as well as A. Winchell * considered the red sandstones and quartzytes of Wisconsin and Minnesota as the conformable downward extension of the light-colored sandstones of the St. Croix and Mississippi valleys which they parallelized with the Potsdam of New York. It was just before the commencement of the Minnesota survey (Feb., 1872, Am. Jour. Sci., p. 93), that Prof. R. D. Irving demonstrated conclusively that at Baraboo, Wisconsin, there was a marked unconformity between the red and the light-colored sandstones, and that they could not belong to the same system. Prof. Irving coincided with Prof. James Hall,** who had previously regarded the light-colored upper sandstones as Potsdam and had been followed by nearly all geologists of America, in referring the lower quartzytes to the Huronian of Canada.

The first report of the Minnesota survey refers the lower quartzytes to the Potsdam horizon of New York and gives the name *St. Croix* to the overlying light-colored sandstones. In the light of all subsequent examinations, both east and west, there has appeared nothing that has disproved the correctness of this reference, but on the other hand every fact, whether of paleontology or of stratigraphy, which has been brought out since 1872, relating to this horizon, has been in accord with it. It must not, however, be considered as sufficiently demonstrated, so long as there are competent dissentients who still restrict the name Potsdam to the later sandstones. It will appear later in what way this bears on the classification of the rocks styled Azoic by Messrs. Foster and Whitney and later Archæan by Prof. J. D. Dana.

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* Owen's report on Wis., Iowa and Minn., pp. 48, 187, and Table, p. 634. Am. Jour. Sci. (II) xxxxii. 226, 1864.

** Report of progress to the Governor of Wisconsin, 1860; also Notes upon the geology of some portions of Minnesota from St. Paul to the western part of the state, *Trans. Am. Phil. Soc.* Philadelphia, June, 1866.

The second annual report, 1873.

In the second report was an account of the geology of the Minnesota valley. While this entered into a somewhat detailed description of the field appearances of numerous outcrops of the crystalline rocks between New Ulm and Big Stone lake, there was no attempt made to classify them, or to refer them to any horizon of rocks exposed in the northern part of the state. They were regarded as a southern extension from the granites in the northern part of the state, and were presumed to have their parallelisms there if they could be referred to their proper places. The red quartzyte at (or near) New Ulm is again referred to the age of the Potsdam.

The sixth annual report, 1877.

The report contains the first recorded observations made by the Minnesota survey on the crystalline rocks of the northeastern part of the state. They were made at Northern Pacific Junction and about Little Falls, on the Mississippi river. An examination was also made of the granitic rock in the vicinity of Motley. These notes are simply descriptive, without any effort at classification.

In this report is a description of the geology of Rock and Pipestone counties, in which are large outcrops of the same red quartzyte as seen at New Ulm, and at Baraboo, Wisconsin. It is classed as Potsdam.

The seventh annual report, 1878.

In the seventh report is a sketch of a somewhat extended systematic examination of the mining geology of the northeastern part of the state. The coast of lake Superior was examined from Duluth to Pigeon point, a trip was made overland from Grand Portage along the international boundary to Basswood (or Basimenan) lake, thence to Vermilion lake, the St. Louis river, across to the Mississippi and down that river to Little Falls. Some examination was also made of the country between Pigeon point and the Brule river by ascending some of the valleys from the shore of lake Superior. Among the geological results of the season's field work, as stated in the report, on p. 10, are the following points which may be classed as advances in classification of the crystalline rocks of the state.

1. The syenites, granites and other rocks that had been named

Laurentian by the Canadian geologists graduate conformably into the schists and slates that had been named Huronian by the same—as designated and defined by Mr. Robert Bell. This is also stated by Mr. Bell in his report for the Canadian geological survey, 1873.* This definition, however, of the Huronian formation, as will appear later in this summary, was incorrect, and the correction was made by Mr. A. C. Lawson who named the schists *Keewatin series.*

2. The gray quartzyte formation, No. 4 of the seventh report, is the iron-ore formation of the Mesabi range and graduates conformably into siliceous iron-charged rock, "which in some places furnishes a valuable iron ore in large quantities."

3. The Cupriferous formations, later known as the Kewenian, or Keweenawan, lies unconformably over several formations, and is interstratified with the beds of the latest.

The evidences of these conclusions are not given in this report. The detailed observations have not yet been published, but a synopsis of them was published in connection with a preliminary description of rock samples collected, in the ninth annual report.

The eighth annual report, 1879.

So far as the eighth report records the work of 1879 on the crystalline rocks, it embraces the descriptive account of the outcrops in the Minnesota valley by Mr. Warren Upham, and some mineralogical notes on the eruptive ranges of the lake Superior region by Prof. C. W. Hall. The observations of the writer in the northwestern part of the state, in 1879, have never been published in full, but a synopsis of them was published in connection with a preliminary description of rock samples collected, in the tenth annual report.

In a preliminary chapter are some mineralogical notes on the "Cupriferous series at Duluth" (p. 22). In this a distinction is drawn between the labradorite rock, or "gabbro," and the red orthoclastic syenite which is mingled irregularly with it, the latter being regarded as the result of local fusion of some of the sedimentary strata, probably some of the strata of the Cupriferous series. The whole trap and Cupriferous series of lake Superior is here assigned to the age of the Potsdam sandstone.

*Report of progress, 1872-3, p. 106.

The Ninth annual report, 1880.

This report gives a preliminary description of 442 rock samples collected in the region of the crystalline rocks northwest from lake Superior, in 1878, with a running brief commentary on their field relations. It contains but little attempt at classification of the stratigraphy. A distinction of unconformity is made on p. 82 between the gray slates and quartzytes of the south side of Gunflint lake and the hydromicaceous rocks of the north side, the two being separated by a conglomerate-breccia, and the more northern rocks being regarded as the equivalent of what the Canadian geologists had styled Huronian. This conception of the Canadian Huronian was derived from Dr. Hunt's having described the Huronian as in the main a mass of greenstones, and Dr. Bell's report on the region westward from Thunder bay in 1872. Observations are recorded on p. 94 indicating a conformable passage from what was then regarded as Huronian to the lower syenites, or Laurentian.

The tenth annual report, 1881.

The preliminary description of rock-samples is continued in this report, embracing those collected in 1879, and extending the list to No. 836 inclusive. There is also a renewed discussion of the Potsdam sandstone and its western equivalents, and a short description of some typical thin sections of the rocks of the Cupriferous, or Kewenawan, in Minnesota.

This report embraces some attempt at partial classification, stratigraphically, of the crystalline rocks.* The strata that comprise the island at Grand Portage bay are described in detail, with references to the rock-samples illustrating them. This is followed by a "Generalized section of the alternating beds of the formation," and of the Animikie (Taconic) and lower terranes to the granites and syenites of the region north of Gunflint lake. It is as follows:

Generalized section at Grand Portage and northwestward to Gunflint lake.

1.	The Palisade rock, or the "red rock."	
2.	Green shales, etc., in the bay east of Red point (Nos. 232, 235 and 239).	
3.	Layer of trap, like 540 (542) seen	14 feet.
4.	Chalcedonic amygdaloid (543) seen	20 feet.

*See pp. 47, 49, 87, 94, 112, 123–136.

5.	Fibrous green trap striking E. and W. through the island and forming its highest parts. In spots it is globuliferous with hard, dark, strong, shot-like pellets about ¼ inch in diameter, (Nos. 544 and 545)........	35 feet.
6.	Even-grained sandrock (546) seen........	8 feet.
7.	Trap bed, finely and irregularly jointed, with nodules of white saccharoidal calcite (547) seen........	36 feet.
8.	Quartzyte (548) seen........	5 feet.
9.	Conglomerate (549) seen........	16 feet.
10.	The rock No. 540, forming the great trap covering of the quartzyte hills at Grand Portage; seen 50 ft.; estimated	250 feet.
11.	The slate and quartzyte terranes seen in the hills at Grand Portage, generally, and along the international boundary as far west as the west end of Gunflint lake, estimated........	400 feet.
12.	Jasper and iron-ore beds of the Mesabi, and southeast of Vermilion lake.	
13.	The micaceous and chloritic schists and slates of Vermilion lake and the dalles of the St. Louis river.	
14.	The mica schists, granites and syenites of the region north of Gunflint lake.	

This takes no account of the great labradorite range, which in some places forms the Mesabi, nor of the iron-ore deposits of Mayhew lake, because these are apparently included in the rock Nos. 258 and 540, or in an immense outflow of molten matter at a date somewhat earlier (V. No. 695 and 816). Nor does it mention the conglomerate at Ogishke Muncie lake, because that is apparently an incident of the slaty and talcose beds included in sub-No. 13; nor the red granite of the region of Brulé Mt., because they are probably a modified condition of the Palisade rock.

Respecting the parallels of the quartzyte strata composing a part of Isle Royal, so far as found in Minnesota, the following statement is found on page 49.

Its dip, color and bedding recall the red quartzyte in S. W. Minnesota, but it is rather less siliceous than that. In the same manner, however, it overlies a coarse pebbly conglomerate, which in the same way indicates its relation to the red quartzyte of Grand Portage island and of Pigeon Point peninsula (No. 290), as well as to the sandrock and shales of Fond du Lac.

Not at that time having realized the fact of the existence of two hematite iron-ore horizons, in two separate and unconformable formations, there are some intimations of the confusion of stratigraphic interpretations which the writer discovered when the effort at general classification was undertaken. Thus, on page 94,—

The "Gunflint beds" (i.e., the jasperoid beds) south of Gunflint lake (see after No. 747) have been associated with the slates and quartzytes of the overlying

formation (i. e., the Animike) rather than with the talcose, slaty beds underlying (see 426), but observations about Town Line and Ogishke Muncie lakes seem to indicate that they are here a part of a schistose, slaty formation, highly inclined, which belongs to the Huronian (i. e., as the Huronian had been described in the region) passing into the great conglomerate of Ogishke Muncie lake."

At the same time the conglomerate about Ogishke Muncie lake was regarded as a single formation, and, while in all descriptions and sections that had been given, it had, as a totality, been grouped as a part of a terrane separate from the Animike, yet there were stated to be some considerations that seem to require it to be considered a part of the Animike (p. 95); and that the horizontal slates (the Animike) as a whole may also pass into the tilted slates as a whole. It will only be necessary to state that this latter idea was one of the errors that are inseparable from the progress of any such investigation. It was recorded at the time as expressive of the stage of interpretation of the facts that had then been reached. Yet it was not wholly erroneous. The facts appealed to, conflicting as they appeared then, are facts still, and they go with numerous other observations to force the abandonment of the idea that the Animike is convertible into the "talcose" or sericitic slates and schists of the region further west, although they do become highly tilted. The former idea, however, when separated from the latter, and supplemented by further statement in harmony with a wider field of observation, has stood the test of all the study and observation that have been devoted to this point, and may be considered as a step of progress, *viz.*, The formation of horizontal slates of the vicinity of Gunflint lake and the international boundary is the same as the highly tilted slate and quartzyte formation that passes into the slaty conglomerate of the region of Ogishke Muncie lake.*

In regard to the epoch of the great outflow of the labradorite rock, the "gabbro," some general statements are given on pages 112 and 113, based on observations at Beaver Bay. which show that this rock preceded the advent of the bulk of the eruptive traps of the Cupriferous. The conclusions are in these words:

* Prof. Irving and the Wisconsin and Michigan geologists, as well as all the Canadian geologists except Dr. A. C. Lawson, so far as known, regard these horizontal slates when broken and tilted and the tilted schists as both included in the Huronian; and Prof. Irving has referred to this hypothetical conversion of one to the other in support of that view. (Copper-bearing rocks of lake Superior, Mon. V., U. S. Geol. Sur., p. 443.)

(1) The Great Palisades are of a rock, the equivalent, geologically, of the slaty quartzyte (Nos. 127 and 528) at Beaver Bay, and below that point; and to the red syenite of the islands below Beaver Bay, and of the west bluff of Beaver bay; and to the red (often quartzless) rock associated with the gabbro at Duluth. These beds also constitute the red bluffs at Tischer's near Duluth, and New London, as well as the red rocks at Baptism river and the East Palisades.

* * * * * * * * * *

(2) The feldspar masses are of the same rock (geologically) as the Rice Point gabbro, and both are the result of copious, and perhaps one of the earliest, igneous outflows of the Cupriferous. * * * The late outflows derived fragments from the "clinker fields" and from the knobs of feldspar already formed, as they passed along; and when these had been covered by later sedimentation such sedimentary beds were also involved in the later upheavals and fusions.

The "slaty quartzyte" here mentioned as the probable equivalent of the Palisade rock, is a firm, purplish felsyte containing some angular quartz grains.

In the discussion of the question—what are the western equivalents of the Potsdam sandstone—the tenth annual report records some departures from the conclusions of the Wisconsin geologists, and reverts to the opinions expressed in the first annual report, to the effect that the Potsdam sandstone of New York is not found at all in the bluffs of the Mississippi river, but that it is more likely to be represented by the red sandstone and shales that constitute, with the associated eruptive rocks and conglomerates, the Cupriferous or Kewenawan formation of lake Superior. It maintains that the Taconic system was established correctly by Dr. Emmons, and that it is repeated in the Animike of Thunder bay, as well as in the Georgia group of Vermont. This last is an important step of progress, in the opinion of the writer, and one that no later discoveries have tended to invalidate. This conclusion was reached by a comparison of the described stratigraphy and the paleontology of the formations involved in the east, with those of the west. The Potsdam sandstone, or quartzyte, in both places lies probably unconformably over the Taconic.

The eleventh annual report, 1882,

While containing some matter relating to the mineralogy and lithology of the state, also embraces a table of the systematic geology of the crystalline rocks. This represents the "Huronian" as extending from the Potsdam formation through the

Taconic, also embracing the formation since named Keewatin by Dr. A. C. Lawson, and the mica schists since named (in the report for 1886) Vermilion group* by this survey. The black slates and the quartzytes of the Animike and the Ogishke Conglomerate are made the equivalent of some of the Taconic. This includes also the iron-bearing rocks of the Mesabi range and Vermilion lake, the "Gunflint" beds and the slates and quartzytes at Thomson. The magnesian sericitic schists of the region of Vermilion lake and north of Gunflint lake, while placed below the Taconic and above the mica schists (which are styled "Montalban?") are doubtfully supposed to represent the true Huronian.

Prof. A. H. Chester, in this report, parallelizes the iron districts of Minnesota, i. e., the Mesabi and the Vermilion ranges, both with the "Huronian," and specially dwells on the resemblance of the Mesabi iron-bearing rocks to those of the Penokee range in Wisconsin. He also calls special attention to the close geological similarity between the Vermilion iron deposits and those of Marquette.

The thirteenth annual report, 1883.

In this report is found the first statement that indicates the necessity of separating the Vermilion ore horizon from the Mesabi ore horizon. See pp. 24, 37. It is here assigned to the formation of "Huronian conglomerates and greenstones" (see Fig. 5, p. 22), the same that in the eleventh report was described (p. 170) as "magnesian, greenish, soft schists, becoming syenitic and porphyritic; seen on the north side of Gunflint lake, along the international boundary at Basswood lake, and at Vermilion lake," the formation of graywackes and sericitic schists which has since been designated Keewatin, the same that in the ninth report was said to be unconformably under the Animike at Gunflint lake.

This report also describes primordial fossils from the red quartzyte of southwestern Minnesota, the same that Prof. James Hall had classed as Huronian, and that had been also regarded Huronian by the Wisconsin geologists. These fossils are *Lingula calumet* and *Paradoxides barberi*, and the beds containing them are supposed to be represented in the lake Superior region by the red quartzyte at the head of Wauswaugoning bay and on

* About the same time the Vermilion group was named *Coutchiching* by Dr. Lawson. Am. Jour. Sci. (3) xxxiii., p. 473.

Pigeon point, which in the tenth report was supposed to be extended to Isle Royal.

The fifteenth annual report, 1886.

A large amount of field-work was done in 1886. It added much to the evidences of the correctness of the general parallelisms that had been gradually wrought out by the survey. It also introduced some new problems, and showed the necessity of instituting some subordinate divisions in the formations that had been spoken of in other reports. It also showed the necessity of abandoning some of the hypothetical parallelizations that had been entertained.

In respect to the gabbro formation, the Mesabi overflow, it was found to be indistinctly separable from another, and earlier, eruptive rock which constitutes a prime feature in the topography, and which occupies a wide belt of country running along north of the gabbro area, its line of direction being rudely parallel with the north limit of the gabbro. A general representation of the geographic areas of the various formations was attempted on a colored geological map of the northeastern part of the state. The gabbro was found to have extended so far north as to have covered from sight the line of strike of the Animike (p. 381) and to have come into contact with the older syenite (pp. 347–49). It was intimated that the Animike formation overlay one eruptive rock and underlay the other, and that it seemed to embrace the Ogishke Muncie conglomerate in its lower portion (p. 381). The entire eruptive rock was found to be in some places a remarkable agglomerate, and in various ways to become changed to greenish schists, chloritic and sericitic, and to embrace in its mass, generally in a manner of unconformity, the jaspilyte and iron-ore of the Vermilion lake region. At the same time this green rock exhibited at times very manifestly some signs of aqueous stratification; at other times no such structure could be found in it, and it merged into a dense, homogeneous, massive doleryte. The graywackes which are in this greenstone formation, fade out by merging into its evidently eruptive condition, but in many places are purely sedimentary, having much quartz as rounded grains and pebbles, arranged in sedimentary layers.

The mica-schist belt which was shown to be stratigraphically below the graywacke-greenstone horizon was named *Vermilion* group, or series. It was said to merge into the gneisses below

sometimes conformably and at others to be united with them through a series of mutually intersecting dikes, the gneissic rock penetrating the schists, in their original condition probably of a basic eruptive, and the latter also cutting the contiguous gneissic masses. These rocks are both also cut by basic dikes of later origin (pp. 290–296).

The lowest rock seen was described as gneiss; but at the same time the gneissic structure was found to not always prevail. This lowest rock, which was accepted as Laurentian, is not only sometimes massive, but it is either granite or syenite, i. e. the dark mineral is sometimes mica and sometimes hornblende, or both at the same time.

The granites and syenites were not all put into the same stratigraphic horizon. The "fundamental gneiss," which manifestly lay below the mica-schist horizon, occupies a distinctly marked stratigraphic place. Such is that seen at the northwest end of Vermilion lake. Not to mention the red syenite which is intimately associated with the gabbro, and is certainly of the same date, in its present condition, as the gabbro, a further distinction was introduced by which the rock of the Giant's range, where the range consists of a narrow and abrupt ridge of granite rock, is separated from the age of the Laurentian, and is shown to be the result of local change in some bedded sediments probably later than the Laurentian — a change that, beginning with a partial crystallization of the beds *in situ* by which fine grained, red-weathering syenite, not distinctly individualized as to its mineral constituents, was produced, and continued, under the action of the same dynamic forces, whatever they are, till a perfect fusion and subsequent extrusion and re-crystallization of the same matter were enacted. This was discussed and roughly illustrated on pp. 347 and 349. Some of the distinct observations are recorded on pp. 352 and 353. The cause of this fusion of the sedimentaries was supposed to be the great eruptive epoch of the gabbro; and this red syenite is made the parallel of the "red rock" of the earlier reports, the red quartz porphyry and the "palisade rock" of the lake Superior shore. The gabbro is not present, however, in all places where this fusion has resulted in extrusion of the acid molten rock, although it is nearly adjacent, or actually overlies the acid rock in many places. In the report this change in the ancient sediments is attributed to the contact of the molten gabbro on them, but there may be and probably are, many places where the extruded acid rock came from some

greater depth, though yet within the super-crust, and its fusion and extrusion may not be attributed to immediate effect of contacting gabbro, but must be supposed to be only a part of a wide-spread and deep-seated metamorphic action that affected the region and culminated in extruded molten rock only along those lines where the dynamic action was most intense. Such a line of intense activity seems to be marked by the location of the narrow ridge known as the Giant's range, at least south and southwestward from Birch lake.

The sixteenth report, 1887.

The results of systematic stratigraphy contained in the sixteenth report, while varying somewhat from those of the fifteenth, in the main are concordant therewith. They were drawn from a special reconnoissance of the region of the typical Huronian, north of lake Huron, and a comparison of the results of that reconnoissance with a re-examination of the so-called Huronian of the Marquette and Gogebic iron regions of Michigan, united with previous knowledge of the region of northeastern Minnesota. In some of these results my brother and myself are not quite in concord, but these differences appertain solely to the possible parallelisms of some Michigan and Wisconsin formations with some in northern Minnesota, and on making further field examinations and research into the comparative lithology they may disappear entirely. In the following summary only those systematic results that are in harmony with the writer's convictions are stated, with some foot-notes that call attention to interpretations that are entertained by my brother.

The name Huronian, if used at all, should be applied only to the strata that were first included under the term when it was introduced and defined, and to their stratigraphic equivalents in other parts of the country. The English geologists do not recognize the formation in the British Isles, but include the strata that are presumably included under this term by the Canadian geologists, in the term Lower Cambrian, which embraces the Primordial fauna. The definition of the Huronian which has been accepted is that of Logan, based mainly on the observations of Murray in the region north of lake Huron, republished in the "Geology of Canada," 1863.* With this understanding the

* It is well known that the Canadian geologists have later extended the term widely beyond its typical region, and amplified its significance, so as to make it cover all the schists down to the gneisses of the Laurentian. Recently, however, Dr. A. C. Lawson has separated these schists from the proper Huronian, and has designated a part of them Keewatin. "Report on the geology of the lake of the Woods region." An. Rep. 1885, Can. Sur.

sixteenth report shows an effort to trace the original Huronian formation through Michigan and Wisconsin to Minnesota, and to ascertain the Minnesota equivalents of some of the minor divisions of the crystalline rocks older than the Huronian.

The Huronian, in its typical locality, embraces three principal members.

1. Red and white quartzyte, granular and sometimes conglomeritic.
2. Slate and gray quartzyte, sometimes conglomeritic, making a conglomeritic slate, or "slate conglomerate."
3. Very fine-grained gray or white quartzyte.

These are fragmental, and show every character that is known to indicate sedimentary origin. The formation embraces no mica-hornblendic schists, no sericitic schists, no typical graywackes, no gneiss or gneissic rock. The beds dip with uniformity toward the south, are cut by doleritic intrusions and are overlain by the products of such eruption. They lie unconformably on a "gneiss" which is admitted to belong to the Laurentian, from which the formation received many and conspicuous boulders. The thickness of the formation may be as great as ten thousand feet. There is considerable evidence to show that the upper quartzyte lies unconformably on the slates and slaty conglomerate, although there was no actual observation of such a relation. The formation also embraces red felsytes and some gray gabbro.

Broadly parallelized this is recognized at once as the Animike of Minnesota, embracing in that term the gabbro and "red rock" Mesabi, the Pewabic quartzyte,* the black slates and gray quartzytes and the Ogishke conglomerate. At the same time the upper quartzyte is provisionally parallelized with the true New York Potsdam sandstone quartzyte.** This quartzyte with its Potsdam characters, including a primordial fauna, is found to exhibit characteristic outcrops in Barron county, Wisconsin, southern Minnesota, southeastern Dakota as well as in New York, and in Vermont where it early received the designation "granular quartz."

Subsequently this unconformable quartzyte was traced through the Marquette iron region of Michigan, and its unconformity on the iron-bearing rocks was observed and figured at two points.

The iron-ore rocks of the region of Marquette are, in the 16th

* For a description of the Pewabic quartzyte see p. 86, 16th report.

** Compare "A great primordial quartzyte." American Geologist, March, 1888.

report, made the parallel of those of Vermilion lake in Minnesota, and hence a part of the Keewatin which underlies unconformably the Huronian. The dioritic group and the gold-bearing serpentine group of Dr. C. Rominger are, together, made the equivalent of the sericitic series (i.e., the Keewatin) of Minnesota, embracing in that the schists that hold the jaspilyte at Tower, the conglomerate of Stuntz island, the Kawasachong rock, the green conglomerates at Ely, the lower portion of the great conglomerate at Ogishke Muncie lake,* the dolomyte at Ogishke Muncie lake, and the "greenstone belt," in general, of the map accompanying the 15th report. This series of rocks is not found in the area of the original Huronian.

The iron-bearing rocks of the Penokee-Gogebic range of Michigan and Wisconsin, however, are not considered to be in the same formation as those at Vermilion lake. They are made to be the equivalent of the slates and iron-bearing rocks of the Animike of Minnesota, and hence of the true Huronian. The evidence of this need not be repeated at this place, although it is not expressed fully in the report here summarized. It will be given more fully in a later chapter in this report. †

An important point was reached, in the 16th report (pp. 97–98), in the separation of the Ogishke conglomerate from the greenstone agglomerate on which in some places it must lie unconformably. They seem to have both been affected by the gabbro epoch of disturbance, and the gabbro was found in different localities to lie on the gently inclined strata of one and the nearly vertical strata of the other.

Facts confirmatory of the origination of crystalline acid eruptive rock, both *in situ* and in form of overflow, from fragmental strata, as before reported in the 15th report, are given again on pp. 104–108 in the 16th. These fragmental strata seem to be some part of the Keewatin, and were originally conglomeritic.

Bearing on the question of the age of the gabbro-red-rock flood, which is taken by the Wisconsin geologists to be the base of the Kewenawan, or Cupriferous, of the lake Superior region, some facts were reported in the 16th report (pp. 85, 87, 88) which show that the gabbro began to be extruded during the deposition of the great quartzyte which overlies the Animike, and that the great mass of the gabbro is of not much later date, i. e., of the age

* My brother, however, regards the Keewatin schists as bearing no relation to the Serpentine group of Rominger. See p. 343.

† On the other hand my brother is disposed to regard the Gogebic ore-bearing rocks as having about the same horizon as those at Marquette, which he does not admit within the Huronian; (pp. 188 and 194). The Penokee rocks, however, he would make Huronian.

of the primordial quartzyte of the Northwest which is considered to be of the age of the Potsdam of New York and the "Granular Quartz" of the Taconic.

2. THE VARIOUS STEPS OF PROGRESS.

If we revert now to the list of problems that were unsolved touching the crystalline rocks of the state in 1872, when this investigation began, we shall see that, by the aid of the geologists of Wisconsin and Michigan, great advance has been made in settling some of the questions then pending.

1. The uncertainty respecting the possibility of making a stratigraphical subdivision of the "Azoic" of Foster and Whitney, or the "Archæan" of J. D. Dana, exists no longer. There is a more or less extended subdivision, sometimes into only two parts but more frequently into three or more, which is accepted not only by the geologists of the Northwest but by geologists who are at work on this group of rocks throughout America and Europe. So far as Minnesota is concerned this subdivision can be carried still further, and six members of the "Azoic" (if the Huronian be included in it) can be described which maintain a constancy of character and stratigraphic position extending into Wisconsin, Michigan and Canada, such that they have to have individual description.

2. The terms Huronian and Laurentian were applied to two of these parts by the Canadian geologists. Though misunderstood, by reason of the contradictory and varied definitions that have been given these terms by geologists later than the descriptions of Murray and Logan, when they are compared with the typical regions in Canada they are found to have definite and easily recognizable application to stratigraphical horizons which are extended over the whole Northwest, if not over the world.

The Huronian formation is satisfactorily established as the equivalent of the Lower Cambrian of Sedgwick. This conclusion is not wrought out in any of the annual reports of the Minnesota survey. It is an inference, however, from two other facts which have been indicated in the foregoing synopsis of the Minnesota annual reports, and it has been urged elsewhere by the writer. These two facts when united constitute a demonstration as incontestable as any mathematical formula, viz.:

The Lower Cambrian is equal to the Taconic,

The Huronian is equal to the Taconic,

ergo

The Lower Cambrian is equal to the Huronian.

We shall not stop here to bring forward anew the evidences on which these premises are based, but will proceed to mention other advances that have been made since 1872 in a knowledge of the crystalline rocks of the Northwest.*

4. The foregoing conclusion involves premises which themselves were doubtful in 1872, and which, in the opinion of the writer, are sufficiently established to be admitted as truths. The first is, that the Huronian of the Canadian geologists is the same formation which was named Taconic by Dr. Emmons of the New York geological survey. It makes no difference except in the greater difficulty involved in making this fact appear to the satisfaction of geologists, how long and how honestly the Huronian has been sustained by competent geologists, nor how long the Taconic has been as honestly ignored by the majority of opinion; if these names were actually applied to the same formation, the sooner it be acknowledged by American geologists and the proper adjustment be made in nomenclature, the better it will be for American geology and the credit of American geologists.

5. The other doubtful premise involved in the conclusion (3) above mentioned, can be considered doubtful no longer, viz.: The Lower Cambrian is the equivalent of the Taconic. There are some who bring trifling objections to the actuality of the Taconic at the horizon of the Lower Cambrian, but the evidence is so strong and is based on so large a mass of concurrent fact and testimony that it is practically demonstrated.

6. The Animike rocks having been shown, first by Prof. R. D. Irving, and subsequently by the Minnesota survey, to be the

* On the identity of the Lower Cambrian with the Taconic, see the writer's papers:

Notes on classification and nomenclature. *Amer. Naturalist*, August, 1887.

Some objections to the term Taconic considered. *Amer. Geologist*, March, 1888.

A great primordial quartzyte. *Amer. Geologist*, March, 1888.

Report of the American sub-committee on the Lower Paleozoic, to the London International Congress of Geologists. *Amer. Geologist*, September, 1888; also the report of the Congress.

The same view has long been held by Jules Marcou, J. Barrande, and by Dr. E. Emmons, and by other geologists later. Compare S. A. Miller. The Taconic system as established by Emmons and the laws of nomenclature applicable to it. *Amer. Geologist*, April, 1888. Also A. Winchell. The Taconic question. *Amer. Geologist*, June, 1888. C. D. Walcott. *Bulletin No.* 30, *U. S. Geol. Survey*, and *Amer. Jour. Sci.*, March, April and May, 1888. Mr. Marcou's principal papers are: The Taconic system, and its position in stratigraphic geology. *Proc. Am. Acad. Arts and Sci.*, Vol. XII, 1884. American geological classification and nomenclature, May, 1888.

On the identity of the Huronian with the Taconic; see, The crystalline rocks of the Northwest, N. H. Winchell, vice-presidential address, A. A. A. S., 1884. At a much earlier date the same view was held by E. Emmons, and by J. Marcou. It has also been stated by A. Winchell in the 16th report, p. 170.

equivalent of the original Huronian, it follows that they are also the equivalent of the Taconic and of the Lower Cambrian, and belong within the primordial zone of Barrande, although the distinctive fauna of the primordial has not yet been found in the typical Animike region.

7. The Laurentian rocks, of the Canadian geologists, are divisible into three parts, having different genesis and age. This fact has not been recognized, so far as the writer is aware, except by the Minnesota survey. These three classes of Laurentian (because they have all been so styled by the Canadian geologists) have been separately recognized by different geologists, both Canadian and American, and conflicting inferences have been drawn from them, which have tended to unsettle the whole foundation on which the Laurentian rests. Some have seen valid reasons for supposing the Laurentian older than the "Huronian" and conformable with it, and have given the details of the facts which show it. But others have seen another class of evidence, equally valid, that tends to make the "Laurentian" rocks of eruptive origin and more recent than the Huronian. And again some similar syenitic rocks have been described by the Minnesota survey* mingled in great masses and areas with the Mesabi gabbro. These three classes have been observed and described in Minnesota, as rehearsed in the foregoing synopsis of the Minnesota work. It is believed that these distinctions are fundamental, and that they extend throughout the Northwest, and that when they are recognized generally by observers many of the apparent discrepances that have been noted respecting the Laurentian will disappear.

8. The Laurentian, then, is easily divisible into three parts, but it would not be claimed, probably, by any one, that the same stratigraphic term should be applied to them, and the question may fairly be considered to which of them does it belong.

Besides the subdivision of the "Laurentian" into three parts, as above noted, a different separation has been recognized by some, viz.: into *gneiss* and *crystalline schists*, on the assumption that the original Laurentian contained such schists. This is a necessary and valid subdivision, from that point of view, and was adopted by Prof. R. D. Irving. It is also approved by my brother, A. Winchell, in the 16th report.

9. The "Laurentian" is therefore partly the result of change

*It seems very likely that this so-called Laurentian has also been described in Canada in the regions where the eruptive gabbro is found.

in situ from old sedimentary strata of Laurentian age, and partly the result of eruptive forces which have caused an extrusion and partial overflow over later sedimentary strata of some of the fused material of the same old strata. Such extrusion has taken place at least at two epochs, and the later one is of the age of the gabbro and may have not risen from so great a depth as the former.

10. For reasons which have been mentioned elsewhere* it appears that by hydro-thermal fusion the deep-seated sediments of the super-crust became crystalline; also that the normal super-crust is necessarily acidic; also that any eruption from the fused portions of the super-crust would not only produce an acid eruptive rock when cooled, but that in the later history of the earth (Cretaceous and Tertiary) such acid extrusions could rarely if ever reach the surface of the earth, but would form laccolites amongst the strata overlying the zone of complete fluidity.

3. The results of the investigation so far as they appear at present.

If these steps of progress be applied specifically to the crystalline rocks of the state, we shall find some such history as the following delineated therein with greater or less distinctness.

The Laurentian age.

The name Laurentian is applied here essentially to the "fundamental gneiss." It does not go so far back as to include the first rigid primeval crust that formed from cooling nor so far subsequent to it as to embrace any noteworthy strata of basic minerals that might indicate a formation different in nature, or manner of genesis from the gneiss. In other words it does not include the "crystalline schists." The rock is essentially gneiss, either granitic or syenitic. It resulted from the fusion and recrystallization of the earliest sediments. It occupied a long period, and one that must have been marked by profound quiet, and by uniform conditions. The siliceous accumulations that were the product of oceanic waves and beaches, began in the shoal parts of the ocean and widened as the dry land increased in area, forming the nuclei of the continents. These sediments must have been siliceous, because such only would remain undissolved by the hot and finally alkaline waters of the ocean. When they

*Compare "Some thoughts on eruptive rocks with special reference to those of Minnesota." N. H. Winchell, A. A. A. S., 1888.

had accumulated to a great thickness they were buried under sediments of another kind, those of the "crystalline schists," marking the opening of another epoch in geological time. Wherever they had been raised above the level of the ocean they constituted the only land areas that existed, and perhaps till this day those areas, or some of them, have not again been submerged.

Distribution of the Laurentian in Minnesota. A large part of Minnesota is occupied by this fundamental gneiss. It is not to be supposed that all the area now occupied at the surface by this gneiss, was originally the land area of the state at the time of the close of the Laurentian age. The lapse of time has brought the earth through many vicissitudes. The original area of the Laurentian has been increased at the surface by the growth of the continent which has steadily expanded and risen higher above the ocean's level. As the later strata have successively been elevated to dry land they have been subjected to such destructive action, first of the ocean's beach-line, and afterward by the agency of the atmosphere, that they have been worn back and have uncovered the gneiss over extensive areas where it was at first hid.

In Minnesota this gneiss must have extended diagonally across the state from N. E. to S. W., crossing the Mississippi river and occupying the region of its headwaters about Itasca lake, and including the region of the upper waters of the Minnesota river. There may be spots, or considerable areas, within this original gneissic belt, where by subsequent deep-seated hydro-thermal fusion these primitive Laurentian sediments have been rendered plastic and then fluid, and have by pressure been extruded through fissures in the crust to the surface, or have been uncovered as laccolites by the destruction of the overlying strata; but wherever these exist they are presumed to show their later origin by their non-gneissic structure, or by their overlying some later sedimentary strata. The distinction, however, between the eruptive condition of the fused Laurentian sediments, and the primitive sediments that have been converted *in situ* into the fundamental gneiss is one that requires more study before it can be defined. That both conditions exist, there is no question; that they can always be distinguished is not to be affirmed.

This Laurentian gneiss is represented by the Basswood lake and perhaps the Saganaga lake granites, and probably by the gneisses that are found in the Minnesota valley from near Morton

northwest to Big Stone lake. Northwestwardly from the Basswood area are others of similar gneiss, which have their extension northeast and southwest, nearly parallel with the extension of the other areas. Indeed the geographic distribution, no less than the geological facts that are observed in the field, favors the supposition that these alternating gneissic belts in the northwestern part of the state show either simply the denuded crests of stratigraphic anticlinals or of upward swells of the iso-hydrothermal fusion that has affected the ancient Laurentian sediments. This question is one that requires further investigation. It is referred to again under the head "Problems still unsolved."

Eruptive Syenite. Closely associated with these belts of fundamental gneiss are areas of massive eruptive syenite. It is a fortunate circumstance that the apex of one of the anticlinals of the gneiss runs near the present natural surface, and its manner of transition from sedimentary to crystalline rock can be observed. It would be more consistent with the tilted, even vertical, portion of the beds at the points where this transition has been observed, to suppose the change was due to the varying depths at which planes of equal hydro-thermal fusion ran below the surface at the time it took place, than to suppose it is due to an actual undulation in successive anticlinals of the same stratigraphic horizon. This favorable apex for observing the genesis of gneiss is in the line of the gneissic belt that runs southwestward from the west end of Gunflint lake, and which apparently is continued in the form of erupted syenite in the Giant's range southwestward from Birch lake. It was observed particularly on the Kawishiwi river (15th report, p. 353) and about the south shore of lake Kekekebic (15th report, p. 367; 16th report, p. 103–107). Whether that part of this gneissic belt which is referable directly to a change *in situ* in sedimentary materials be of the same agé, i. e., on the same stratigraphic horizon within those sediments, as others that exist further northwest or not, they are here considered to belong to the Laurentian age in so far as they have not been entirely fused and extruded in a liquid state so as to form erupted rock.

It has already been remarked that the erupted massive form of the acid Laurentian is closely associated geographically with the gneissic. Whether they were of contemporaneous origin is not certain. But that the erupted condition was in some cases produced subsequent to the age of the "crystalline schists" is

evident from the fact that such rock replaces and cuts those schists. This fact has been recorded many times. One of the most remarkable replacements of the dark schists by the bodily transference of syenite is seen north of Gunflint lake, and is described and mapped by Mr. Grant in this (17th) report. That some other areas of syenite were of considerably later date, possibly so late as to have flowed over the Keewatin (greenish, or hydro-mica) schists is indicated by observations made by H. V. Winchell along the Giant's range southwest from Birch lake, and by myself on the shores of Kekekebic lake, where a conglomerate porphyroidal rock passes into gneiss, and directly overlies some Keewatin schists. That other of the erupted syenites of the state are as late as the gabbro, and hence overlie the Animike, is shown not only by the syenites associated in mutually intermolten sheets with the eruptive gabbro that overlie the Animike, but also by the observations made at the Aurora mine in Michigan (16th report, pp. 58 and 187). This is indicated also by the observations and conclusions of Maj. T. B. Brooks and by Dr. C. Rominger in respect to the age of some of the granite rocks of Michigan.*

The age of the Vermilion schists, or "crystalline schists."

It has been remarked† that the mineralogical difference be-between the gneisses and the dark "crystalline schists" is so great that it is allowable to attribute to the latter a different method of genesis, one sufficiently distinct to have introduced a different geological time or age. This fact was recognized in 1886, and the rocks that mark the opening and continuance of this new epoch of time were separated under the name "Vermilion group." A similar series of schists had been noted by Lawson in the region of the Lake of the Woods in 1885,‡ but, while separated by him into two parts, viz., "Schistose hornblende rocks," and "mica schists," had been by him embraced under the general term of "Keewatin series," and considered as the basal part of that series, and assigned to extra-Laurentian time. Subsequently Mr. Lawson identified the mica-schist group

*T. B. Brooks, on the youngest Huronian rocks south of lake Superior. *Am. Jour. Sci.* (3), xi, 206.
Carl Rominger. *Geological Survey of Michigan*, Vol. IV, p. 22.

†A. Winchell.

‡Report on the geology of the Lake of the Woods region. Report C. C. of the Canadian survey, 1885, pp. 37, 54.

and the basal portions of it (the hornblendic schists and the eruptive features that characterize the horizon) in the region of Rainy lake, and has given a description and a name for the mica schists. (*Am. Jour. Sci.* June, 1887, p. 473). He includes the mica schists under the term *Coutchiching*, and supposes the changed eruptive rocks which intervene geographically between them and the belt of Laurentian gneiss lying next north (along the northern shores of the southern part of Rainy lake) to be of later date than the schists.

A similar group of mica and hornblendic schists had been noted in Michigan by Brooks and in Wisconsin by Irving and been placed in the Laurentian. Rominger included the same in his "granitic group" (Geol. Mich. Vol. IV, p. 17–18). Higher in the stratigraphic series, i. e., between the magnesian soft schists and the gneiss and gabbro of the post-Huronian rocks,* another formation of mica schist was observed by them, which they placed near the summit of the "Huronian." They gave neither of these any special designation. In New Hampshire the "Montalban series" is one essentially of mica schists, but† whether it can be parallelized with either of the northwestern horizons of mica schist is a question which the future alone will be able to answer.

Hornblende schists converted to mica schists. To the writer, however, the micaceous and the hornblendic characters seem to be so blended, and the one so frequently substituted for the other, that the two parts described by Mr. Lawson appear to be only phases of the same set of rocks. The hornblendic condition, as schists, is without doubt the fundamental and primary one; and that one is found nearest the gneiss of the Laurentian. Hornblende is easily converted into biotite; biotite has so close relations with muscovite that it is sometimes twinned with it in the same crystal; muscovite is replaced both across the bedding and along the strike by hydro-mica or pearl-glimmer, and the last passes insensibly into the talcoid "Keewatin stuff"‡ of the Keewatin series. There is a conformable succession, both genetico-mineralogical and stratigraphical, from the hornblende schist through the mica schist into the hydro-mica schist, by which these are bound fundamentally into one group, as placed by

* Geology of Wisconsin, Vol. III, 1873–79, pp. 93, 145, and table between pages 436 and 437.

† Geology of New Hampshire. C. H. Hitchcock, Vol. II, p. 112.

‡ A. Winchell. Sixteenth report, p. 343.

Lawson, and no other sort of transition is known or indicated. On the other hand, bearing in mind the strong mineralogical break, or contrast, between the gneiss and the hornblende rock, there is not so close a mineral relationship with the Laurentian. There is also, in some places, as profound a stratigraphic break and non-agreement. This is shown in numerous descriptions and illustrations not only of Mr. Lawson, but also by the 15th and 16th reports of the Minnesota survey. Mr. Lawson emphasizes this fact by a remarkable inference, viz., that the Laurentian is eruptive and of later date than the Keewatin schists. Not to dwell on this inference at this time it is sufficient to call attention to it to show the probability of a plane of profound discontinuity between the Laurentian, as here defined, and the Vermilion group.*

Nature of the transition from the Laurentian to the Vermilion. As to the nature of the dynamic agent which introduced this change in the crystalline rocks at this horizon, it is indicated by the nature of the rocks themselves. Primarily they are characterized by the minerals that constitute a basic eruptive. They are found to exist at first as structureless knobs of dioryte or doleryte. These lie nearest the gneiss (15th report, p. 330). They are flanked by basic rocks of various modifications, among which hornblende schist is predominant. Gradually, on receding from these black knobs, a sedimentary structure becomes apparent, and the hornblende is replaced partially or wholly by black mica. At last the rock is changed to a nicely stratified mica schist which at first is perhaps very dark-colored and firm, with little free silica, and subsequently, with an increase of silica, is striped with distinct strata of granular silica. As the dark mica still further fades out the mass is converted to a fine granulyte or quartzyte, or a light-colored mica takes its place and the whole passes into sericitic schist or graywacke.

It is not always the case that all evidence of molten condition is wanting at this horizon of transition from the gneiss. But it is very slight at most of the sections which have been described.* If, however, but a single unquestioned occurrence of eruptive conditions be found at this point it is sufficient to warrant the hypothetical introduction of a general eruptive epoch,

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*Compare, A. Winchell; 15th Report, pp. 41, 43, 87, 97, 180: H.V. Winchell; 16th Report, pp. 407, 416, 417, 419, 455, 456: N. H. Winchell; 15th Report, pp. 291, 338, 349; 16th Report, pp. 76–77: M. E. Wadsworth; 15th Report, p. 331.

*Compare, however, Lawson, Can. Rep. 1885. C. C. p. 41; Am. Jour. Sci. June, 1887, p. 477.

so widespread as to constitute a change from one system of rocks to another. No one can read the descriptions given by Mr. Lawson, or some of those contained in the 15th and 16th reports of the Minnesota survey, without recognizing not only one point but numerous points where eruptive characters are stamped at this horizon not only on the basic rocks of the Vermilion but also on those of the acidic "Laurentian." They mutually interpenetrate each other in the form of transverse dykes and mutually embrace isolated fragments separated each from the other. It seems to be abundantly demonstrated that some sort of dynamic change was introduced. The only inference that such a demonstration points to, in the light both of the contrasted lithology and the interrupted stratigraphy, is that of volcanic action.

Having now fairly stated the nature of the change which is presumed to set off the Vermilion rocks from the Laurentian, it is necessary to consider, further, whether the gradual and conformable conversion of the Laurentian beds into the Vermilion, such as has been seen at many places, and which indeed is the most frequent manner of transition,* is consistent with the hypothesis of an epoch of eruption. It should be remembered that the beds do not now hold the position they had when they were deposited. They stand now nearly vertical. While this upturning facilitates the deciphering of their history, it has been accompanied by such changes in the crystalline condition of their elements that a screen that partially conceals their history has been thrown over them all; yet through this screen can be seen the outlines of their historic and dynamic genesis.

Admitting the actuality of a period of volcanic action at the opening of the Vermilion age, it is evident that the eruptions would take place only at centers of intensity of pressure. Once located, such vents would for longer or shorter periods continue to send forth the eruptive matter. In the presence of the almost world-covering ocean these materials would be at once distributed, dissolved, deposited, in the same manner as sediments at the present day, excepting only that probably the solvent power of the ocean's waters was greater than at the present time. The former sediments having been almost wholly of an acid nature,†

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* Mr. A. C. Lawson has described such in his report on the region of the Lake of the Woods, pp. 73, 76, 83. See also A. Winchell; 15th Report, pp. 97, 101, 178; 16th Report, pp. 264: H. V. Winchell; 16th Report, pp. 405, 415, *et passim*: N. H. Winchell; 15th Report, pp. 296, 298; 16th Report, pp. 69, 70, 76.

† That is, containing over 60 p. c. of silica.

such that when crystallized again they constitute the fundamental gneiss, they must have been accumulated slowly. But on the advent of this new supply of material, which is so rapid that it can not all be worked over by the ocean so as to be dissolved and its alkaline elements extracted, the erupted materials are thrown down in the condition of stratified sediments, retaining to a great extent their chemical composition. In the periods of comparative quiet these basic materials are interbedded with more siliceous materials, such alternations taking place as long as the supply of basic material is intermittent. Thus might be formed a great series of strata, surrounding the volcanic centre, thousands of feet in thickness, which would be made up of variously interstratified or mixed siliceous and basic sediments. Sometimes there would be intrusions of purely basic doleritic rock among these sediments, at different horizons, due to the bodily overflow of sheets of lava among the sediments,* in a manner similar to the interbedding of trap rock in the Kewenawan at a later date. In other places these eruptions might take place somewhat later, involving in fracture, upheaval and mixing the last made strata in forms of various fragments and breccia in the molten rock that escaped.** Such an epoch of disturbance, sufficient in its force to cause the outflow of basic rock from a deep source, would probably be sufficient to fuse and cause the outflow of some of the sedimentary rock that already had been formed. Thus the basic and acid rock would mutually interpenetrate, and a series of fractures which would be filled by the injection of any fused material that was adjacent, would be perpetuated to the remotest time in the form of transverse and more or less concordant dikes and by breccias composed of the two rocks.

It is manifest, therefore, that the supposition of the advent of a characteristically eruptive era, closing the quiet Laurentian sedimentary age, will account for both an unconformable and a conformable transition, such as are seen, from the Laurentian to the Vermilion.

Effect of hydrothermal fusion. It is necessary, before proceeding to the consideration of the next age, to call attention to another great fact in connection with the history of the Vermilion. Nothing is more evident to the geologist who carefully

* H. V. Winchell seems to have encountered such in that great extension of the Vermilion northwestward from Vermilion lake to Rainy lake. See, specially, 16th report, p. 425.

** See the 15th report, p. 333, and p. 337.

inspects the Laurentian and Vermilion strata, than that they have had, in some respects, a common experience. This, however, is subsequent to the date of the origination of the rock masses, and has had a tendency to so unify their mineral characters as to blend them, in the opinion of some geologists, indissolubly into one system. They contain, excepting the eruptive diabases, etc., at the base of the Vermilion,—essentially the same mineral components; but those components are differently distributed and exist in very different proportions. These minerals are interlocked with each other in crystalline contact. It is very difficult to affirm, in many places, any fragmental grains. They lie in such continued parallelism in long sheets that there is no natural agent except sedimentation that can be appealed to to account for the stratification. The strata do not consist of individual minerals, that is, any single stratum may contain several minerals, but they change in relatively proportionate amounts in a direction across the strike, and this slow change, which on weathering brings out either light or dark bands, is so gradual that some of the strata or some parts of the strata, can not be separated from the others by any accepted designations. Within the same band the gneissose aggregation changes to a schistose. While in a general way it may be said that the mica schist alternates with what Mr. Lawson has conceived to be a series of thin gneissic dykes in as many sedimentary beds of mica schist, it is equally true, and equally as evident on inspection, that the schist fades out across the beds, into gneiss by a change in the relative amounts of the constituent minerals. It is very certain that if the schist, in such places, be attributable to sedimentary origin the gneiss is equally so.* Indeed often within the gneiss itself are distinguishable narrow, parallel belts of varying color and lithology at some distance from the horizon at which the general gneiss mass began, which must be attributed, as certainly to the same cause as in the schist. These only lack the dark coloring minerals to show their nature more evidently, and their similarity of origin with those unquestioned parallel belts that mark the schist.

This crystallizing and unifying of the mineral characters must have taken place in these strata while they were yet buried at considerable depth below the surface, or at least at such a depth that they were affected simultaneously by hydro-thermal fusion.

* Compare H. Reusch, *Boemmeloen og Karmoen med omgivelser geologisk beskrevne* (English summary), p. 389, 1888.

Whether before, during, or subsequent to the process of upturning which has brought them both to a vertical attitude, it is not necessary here to inquire. Indeed, this is yet one of the "unsettled problems."

The Keewatin schists.

This term is here used in a sense somewhat restricted from that in which Mr. Lawson first applied it, inasmuch as it does not include the crystalline schists. This change, however, will doubtless be considered allowable, since Mr. Lawson himself seems to have separated the original group into two series by the application of a distinctive term to the mica schists — the Coutchiching.*

Conformable transition from the Vermilion. It has already been stated that structurally there is a conformable transition from the Vermilion to the Keewatin. This has been found to be the case without exception, so far as the Minnesota survey is concerned, and it seems not to be contradicted by any facts reported by Mr. Lawson. Indeed, so far as Mr. Lawson has reported any facts,** they tend to harmony with the facts and conclusions of this survey. Very favorable opportunities have been afforded for the minute inspection of these beds where they pass to the Vermilion, in many places, and they are reported in the fifteenth and sixteenth reports. There have been five different geologists, engaged within the last three years by the Minnesota survey, who have made independent examinations at this horizon of transition, and at separate places, and in every instance they have reported a gradual and conformable transition from the Vermilion to the Keewatin.

There is also a corresponding gradual change in the crystalline condition and the composition of the beds. While the materials are referable very largely to the same source as the materials of the Vermilion, there is an increase of quartz and a loss of mica in ascending in the strata. The schists become sericitic, or chloritic, or argillitic, and are interbedded with graywackes and agglomerates; the last prevail near the top and indeed seem to have introduced the marked eruptive characters that distinguish the next formation.

Nature of the Keewatin rocks. It appears, from the character of

* Am. Jour. Sci., June, 1887, p. 477.

** Am. Jour., June, 1887, p. 477.

the rocks of the Keewatin, that active volcanic vents existed throughout the whole period, and that the ejectamenta were received in the waters of the surrounding sea. The strata contain much silica, in rounded grains and pebbles, indicating the waning of the volcanic supply and the influx of sedimentation similar to that accumlated during the Laurentian. There are dykes and various diabasic rocks associated with the Keewatin strata, some cutting transversely and some nearly, but not quite, parallel with the strike, some of which are certainly of a later date, but of which some seem to belong to the age of the Keewatin. Whether any of these have any possibly traceable connection with some of the old volcanic vents, existing within Keewatin time it is not now possible to state, but it is very likely that such connections will ultimately be established. At any rate the Keewatin closed by a renewal of active eruption as profound in its energy and its effect on the pre-existing strata as that which marked the close of the Laurentian. In the vicinity of Tower and thence eastward the rocks that evince this epoch of volcanic eruption have been insepcted at many places, and they are described with accompanying illustrations showing the crumpled and faulted condition of the earlier aqueous strata, in the fifteenth annual report (pp. 223–275). The rocks which resulted from this renewal of igneous forces form a conspicuous series and they have been traced almost continuously from Tower to the vicinity of Gunflint lake where they pass below the Animike. They show the same confused blending of stratified with massive rock as has been mentioned at the base of the Vermilion. In many places they constitute hills that rise one hundred to three hundred feet above the adjoining lowland levels, and consist of a greenstone that exhibits all the outward characters of diabase or doleryte. At many places this greenstone is agglomeritic, some of the stones showing, by a periphery of amygdaloidal structure, that they were immersed in a magma that differed from them in the amount of contained heat, or in their capacity for receiving and transmitting heat. The massive structure sometimes embraces large fragments rent from beds of stratified structure, and the massive structure itself sometimes acquires a faint lining and then a distinct banding which cannot be attributed to any other known agent than sedimentary action. The greenstone is frequently jointed in a columnar manner, forming basalt, in which cases it seems necessary to regard it as a primary basic eruptive. All the other modifications and exceptions which this

greenstone exhibits causing a departure from the characters of a normal basic eruptive are to be referred to the action of the ocean on the erupted materials, or on the local rupture of the pre-existing strata and the mingling of the fragments with the new materials. It is evident that in some places these fragments would be gently covered and inclosed by new sedimentation (and such instances are shown on the south shore of Vermilion lake) producing the curious alternations of breccias and parallel strata, all of the same kind of rock, which have excited the wonder of more than one geologist. It is equally evident that in other places these fragments would be covered by an overflow of erupted material that did not come into contact with the ocean's distributing action, and there would result a basalt containing angular masses of fragmental strata. It has been observed that apparently the most massive rocks of this epoch change by weathering into a green chlorite or even a sericitic schist, when they occupy the lower levels and come into contact with water, or where they are subjected to unsheltered exposure to alternating frosts and moisture. In this case the original rock shows, sometimes, a sedimentary banding, and the schistosity that results may or may not coincide with the direction of this banding. Throughout nearly all the region where this greenstone prevails, the schistosity has a prevalent direction northeastwardly, and that is also the direction of the general strike of all the sedimentary rocks; but there are exceptions in the case of the sedimentary strike, which are more numerous and extensive than any that have been found in the direction of the schistosity. The ease with which this schistose structure is developed on weathering, seems to vary with the composition of the rock, or at least with its original structure. Where the greenstone is evidently a true eruptive basalt which has never been subjected to the distributing action of sedimentation the schistose structure is faint, or is wanting, and rounded knobs of structureless massive rock rise above the general level of the country. When there is an intimation of the primeval action of water on the constituents of the rock at the time of their deposition, evinced either by the presence of siliceous grains, the inclosure of fragments of stratified masses, a generally lighter green color in the whole mass, or in an indistinct banding like sedimentary structure, the schistose structure is more quickly developed.

Vermilion iron ores. The Keewatin is the iron-bearing forma-

tion of the region of Vermilion lake. It contains the jaspilyte lodes which have been described at Tower in the 15th annual report. But it should be stated that these lodes seem to prevail in those parts of the formation that show most evidently the characters of massive and original eruptive rock, i. e., in the later portion. The knobs of jaspilyte at Tower are embraced in and penetrated by a green schist which at the surface is easily excavated, when a schist, but which at greater depth sometimes becomes a massive green rock, and which in the main must be considered an original eruptive. At short distances from the knobs, even on the slopes an evident sedimentary structure supervenes, the beds being nearly or quite vertical.

Origin of Jaspilyte. It is not necessary here to reconsider fully the question of the origin of the rock known as jaspilyte. Various considerations are given in the 15th report that go to show that it is of sedimentary origin, embraced as foreign masses in the green eruptive rock of the region. Much more study has since then been given to the subject, and while the facts and arguments then relied on are still valid some other problems have arisen which need to be solved in order to make the hypothesis of its sedimentary origin entirely satisfactory. They can be briefly referred to, viz.:

Why is the silica of the jaspilyte so uniformly of very fine grain, and of so uniform a grain?

Why does the jaspilyte accompany the most evidently eruptive parts of the Keewatin, and why is it not found in important masses in those parts that have plainly a sedimentary structure?

It seems quite remarkable that the jaspilyte, on the sedimentary hypothesis of its origin, should not vary perceptibly in the size of its siliceous grains. Reference is here made to the ultimate quartz grains into which it disintegrates on being long-weathered. When, in the stratified schists, some small pebbles from the jaspilyte are disseminated in the manner of sedimentation, the pebbles themselves, as constituent elements in the stratified mass, are seen to vary in size considerably, some of them being no larger than the eye of a needle, and others as large as pease, or even much larger. The same is true of pebbles of other silica, such, for instance as those of segregated or chemical silica which does not show the finely granular structure. But when these pebbles of jaspilyte are examined more closely they are found to be made up of almost microscopic quartz grains of the same size. The question refers to the size of these.

If they are the product of sedimentation, it would be in accordance with usual observation that they would have been collected and deposited under the action of varying currents and would vary in size from place to place, or from structure to structure (within certain limits) and some of them would be expected to be mingled with other sorts of sedimentary materials. Some observations have been made, indeed, which indicate the mingling of fine siliceous grains, supposed to be the same as the fine grains of the jaspilyte, with the sedimentary green schists in the vicinity of Tower,* but in these cases, and especially in the case of principal masses of jaspilyte that are mined at Tower, it is not yet sufficiently shown that the ultimate grains of which the jaspilyte consists, manifest such a variation as is here indicated. Indeed it is quite possible that all the siliceous grains that are seen disseminated through the green schists, as seen at Tower, are compound grains, derived as fragments from jaspilyte that pre-existed as such, and that each one can be reduced, on examination, to the same minute granules as the jaspilyte itself. Therefore the question remains unanswered—why are the ultimate granules of the banded jaspilyte of so uniform a size, and so uniformly fine?

Again, it seems quite remarkable, on the sedimentary hypothesis of the origin of the jaspilyte, that it should be found, in its most typical forms and largest amounts, embraced in a rock which manifests the least of the characters that indicate sedimentary forces, and surrounded by rock that manifests unquestioned, or almost unquestioned, eruptive forces in its manner of origin.† This association is hard to explain except on the eruptive hypothesis for the origin of the jaspilyte. It might be said, with much reason, that in the midst of the basic eruptions, or at intervals of rest from basic eruptions, some acid eruption took place, and that the erupted matter assumed such forms, and such relations to the basic, whether in the presence of oceanic waters or on land, as the circumstances required, in just the same manner as the materials of basic eruption. To this the mineral nature of the jaspilyte is the greatest obstacle.

Name. The massive "greenstone" stage of the Keewatin has no distinctive name. It has sometimes been referred to as the

* Fifteenth report, pp. 226–230.

† Attention has been called to the distribution of the jaspilyte masses by Mr. H. V. Winchell *American Geologist*, January, 1889. *The diabasic schists containing the jaspilyte beds of northeastern Minnesota.*

"Kawasachong rock," since it forms the falls of that name at the mouth of the Kawishiwi river, on the south shore of Fall lake. But it is not desirable that such a name be perpetuated. *Kawishiwin* would be better, and it would be appropriate since this river runs for many miles, and some of its tributaries for many more, over rock belonging to this epoch of the Keewatin.

Parallels of the Keewatin. The writer has seen at but one place in the Northwest, outside of Minnesota, what he believes is the stratigraphic equivalent of the Keewatin. This belief rests entirely on lithological resemblance, with some general stratigraphic parallelism. In general, the groups which Dr. C. Rominger has described as "serpentine group" and "dioritic group,"* in the region of Marquette, exhibit the characters of the Keewatin. There may be, as thought by him, an essential difference between the dioritic and the serpentine groups, but their affinities are very close, and indeed nearly all the characters, in limited areas, are found in the Keewatin. The serpentine rocks may ultimately be found to consist of the old volcanic cones, now tilted to lie at an angle of 90 degrees, more or less, from the position they originally occupied, from which issued the ejectments that were consolidated to form the dioritic schist group. In that case they would fundamentally be of about the same age as those schists. However that may be, no one can read the careful description of the dioritic group by Rominger, be he familiar with the Keewatin, without being struck with the great mineralogical similarity. (See also 16th report, pp. 47–48.)

There is, however, an important evidence of this parallelism to be drawn from a comparison of the stratigraphy. In the Marquette region the mica schist group is but feebly represented, and is not at all shown by Rominger on his map of the region. It is included by him in his granitic group. But the dioritic group comes at once into contact with the granitic rocks of the "granitic group." This is shown to be interbedded sometimes with the base of the dioritic group, and the granite to be apparently produced sometimes by the fusion and extrusion of some of the beds of the dioritic, or from some of the lower strata, forming knobs and sudden enlargements of granitic rock within the schists of the dioritic group.† The same kind of indistinct, incipient crystallization as described by him has been noted at about the same horizon in the schists of the Keewatin north of

* Geol. of Mich., Vol. IV, pp. 22, 24, 26, 27.

† Geological survey of Michigan, Vol. IV, 1881.

Gunflint lake, and between Ogishke Muncie and Kekekebic lakes, and the same gradual inter-bedded transition from the schists to a sub-granitic rock. In the same way also great overflow areas of acidic syenite or "granite" are found in connection with both.*

But the most remarkable stratigraphic coincidence is the relation of the Keewatin and the dioritic group to the overlying formation. In Minnesota it is the iron-bearing Animike, and at Marquette, it is the "iron group," of Rominger. This relation is one of unconformity. For evident reasons, which need not be elaborated here, the "iron group" of Rominger is considered to be on about the same stratigraphic horizon as his "arenaceous slate group." They are not shown by him to be distinct, although he supposes them to be separated by the "quartzyte group," and in both of them are found important bodies of ore in the Marquette district. They have the same relations to the dioritic group, as described by him, and their geographic distribution, as separately delineated on his geological map, especially when taken in connection with his geological descriptions, is inexplicable on the supposition of their separate identity.

In the light of what has been published by the Minnesota survey respecting the unconformable superposition of the Animike over the Keewatin, nothing further need be said as to that fact. But when this unconformity is extended to the Marquette region, and the iron-ore beds there so much worked are placed above that line of unconformity, it may need a concise statement of the evidence to make it appear plausible. While it is in perfect accord with the published conclusions of the Michigan and Wisconsin geologists, to put the ore-bearing rocks of those states in the "Huronian," it is not in accord with them to separate that horizon from the dioritic schists which really embrace an ore horizon of an older date, by a plane of unconformity; but under the term "Huronian" have been grouped, in one essential concordant series of strata, all the rocks of the district younger than the fundamental gneiss or the Laurentian. Later Dr. Rominger has stated that some of the granite of the district is eruptive and of later date than the associated schists. (Geol. of Mich., Vol. IV, pp. 17 and 22.)

The reader is therefore referred to the following quotations

* The hematite lodes at Tower seem to have their representatives in the dioritic group of Rominger, but they have not proved productive enough to support regular mining. Such are mentioned by him on pp. 25, 27, 29, 30.

from the descriptions of Dr. Rominger of the relation of the "dioritic group" to the overlying "iron group" and "arenaceous slate group."*

Page 72; Speaking of the surface rock of the environs of Negaunee and Ishpeming, which belong to the "iron-ore group," he says: "The strata are in an exceedingly disturbed condition * * * These disturbed beds lie, in every instance, directly, but very often unconformably, on chlorito-hydro-micaceous schists, or on crystalline dioritic masses which are constant associates of these chloritic schists." * * * "Overlooking the extremely plicated and corrugated condition of the strata, they form, considered in their totality, a synclinal basin, hemmed in between dioritic ridges."

Page 76; "The discordance existing between the dioritic and the iron-bearing rock groups is obvious in the majority of natural or artificial exposures, although it often occurs that they adjoin each other in parallelism."

Page 82; "The ore-bearing beds in the lake Superior mine lie in a steep inclination, with northern dip directly on the diorite, or on schistose beds belonging to this group, but in other parts of the mine the strata are seen to be bent and folded repetitiously, and to dip in the most irregular way."

Page 83; "The deposits visibly underlie the jaspery massive rock-ledges and repose in a much corrugated condition on the schists of the diorite group."

Page 86; "In the abandoned pits of the old Tilden mine, and in several neighboring natural exposures, the ore-formation is found to repose on the diorite, or on the schists belonging to this group, but, as it seems, always in discordance."

Page 108; Speaking of the "arenaceous slate group," he says: "The strata lie on the side of a diorite hill dipping under a low angle toward it in a northern direction, and a few hundred steps further east another body of these ledges lies in a slanting position on the diorite."

Page 114; "On the south side of the large cluster of diorite knobs, north of the New York mines, we generally see the ore-formation in direct contiguity with the diorite; but on the higher part of one of the rock bluffs another kind of stratified rock [i. e., the arenaceous slate group. N. H. W.] is found to repose on the diorite in seemingly discordant position."

These statements are sufficient to show that in the Marquette region there was a profound break, or unconformity, that separated the dioritic group from that next succeeding, as marked and as general, as that which separated the Keewatin from the Animike. The fact that it has not generally been recognized, and when so observed that its significance was not noted, may be explained by the great confusion that prevails at Marquette in all the dip and strike of the rocks, due to disturbances that involved both the older and the later terranes.

Further evidence of this parallelism is found in the fact that,

* Geology of Michigan, Vol. IV, 1881.

in the same manner the Keewatin, and the "dioritic group" of Rominger, are unconformably overlaid by a more recent quartzyte, as will appear later in this review.

Jaspilyte is in the Keewatin and the dioritic group. There is a general lithological resemblance as already noted. It will be necessary here only to call attention to one. The Keewatin contains the typical jaspilyte deposits of Minnesota—i. e., those that have chalcedonic silica as their chief characteristic, and occur in curiously ribboned contorted bands or masses, affording a hard specular hematite. Although Dr. Rominger does not employ the term *jaspilyte*, he seems to make several references to it in connection with his account of the dioritic group. Such references may be found on pp. 27, 29, and 30. In other places it seems as if the descriptions that he has recorded of the phenomena of the iron mines, all of which he supposes to be in the "iron group," and not in the dioritic group, can apply only to the dioritic group. This is true particularly of some of those in the vicinity of Ishpeming. Dr. M. E. Wadsworth's observations and figures* seem to indicate the same. The manganesic soft hematite, and the limonitic ores, which are also "jaspery," are not believed to belong to the same formation as the hard jaspilyte-hematite, but to the overlying "iron group." It is true, however, that it is impossible, at present, to indicate fully the petrographic difference that may distinguish the jaspilyte-hematite of the Keewatin from the jaspery beds of the iron-ore group. That will be subject for further study.†

Possibility of rocks younger than the Keewatin, before the beginning of the Taconic. We have seen that the Keewatin was terminated by an increased eruptive activity, producing distinctively, in Minnesota the "greenstone range," or the Kawishiwin rocks. We have no distinct knowledge of any later sedimentary beds prior to the unconformably overlying Taconic (or Animike). There are, however, some problematical rocks that different members of the Minnesota survey have noted whose position in the stratigraphic column has not been determined. They have been designated *muscovado rocks*, and in some places they hold a position

* Notes on the geology of the copper and iron districts of lake Superior. *Mus. of Comp. Zoology.* Geol. Series, Vol. I.

† The reader is referred to the rock "talcose conglomerate," described by Dr. E. Hitchcock in the *Geology of Vermont*, for a probable New England representative of the Stuntz conglomerate of the Keewatin. Indeed there is great reason to suspect that the Keewatin horizon in all its features exists in the "talcose slates" of western New England.

some distance south of the strike of the Kawishiwin and spread over several miles of area. It is not intended to discuss them here at any length. They may be some part of the Taconic, and it is only suggested that they may be a sedimentary formation that accumulated subsequent to the Keewatin before the submergence that brought the Taconic unconformably over it.

The age of the Taconic (Animike, Huronian).

How long an interval of time passed, and what its events were, separating the Kawishiwin epoch from the Taconic, it is impossible to state. But it is evident that there was a great change in the surface of the earth, wherever this succession is found, which tended to allow not only submergence of some of the pre-existing land area, but such general quiet, speaking broadly, as would allow slow sedimentation, and apparently the growth of plants and animals. The black carbonaceous shales and slates, or in other places the graphitic character of the rocks of the Taconic, where, as on Pigeon point, they have been metamorphosed, sufficiently indicate the presence of plant life in the Taconic. In other places faint tracings of rude forms, apparently of vegetation, have been observed on the sides of some of the black slates. But of these forms none from Minnesota have been carefully examined and described.* Of animal remains none have been found in Minnesota that belong in the black slates, but in the quartzyte overlying, some primordial fossils have been found† corresponding with the fauna of the Paradoxides horizon of eastern North America, indicating, so far as this evidence goes, the age of the "Granular Quartz," and of the Red Sandrock of Vermont. This formation seems to be represented in the Rocky mountains, where the primordial fauna has been mentioned by Mr. R. G. McConnell‡ along the line of the Canadian Pacific railroad. Still earlier Mr. C. D. Walcott described it in Nevada. § There is no doubt that this formation is widespread. The coincident identity of the old Taconic with the "Lower Cambrian" and the Huronian need not be discussed here, and those who believe that these represent different rock-horizons will, of course, not accept the generalized

* Sixteenth report, pp. 78, 239.

† Thirteenth report, p. 65.

‡ Geol. Sur. of Can., 1886. Rep. D., pp. 29–30. Am. Geol., January, 1889.

§ Thirtieth bulletin, U. S. Geol. Survey.

history that is here indicated. To the writer there seems to be no way to group the terranes that are found in the Northwest, subsequent to the Keewatin, belonging in that general horizon that has been accepted widely as "Huronian," except to make them the parallel of that earlier-named system which was so long studied by Dr. Ebenezer Emmons, and by him named Taconic.

The opening of the Taconic. So far as we know the Taconic was characterized, from New England to the Black Hills, by an epoch of increased submergence beneath the ocean. There is great reason to believe that all the earlier formations of the super-crust had been subjected to great flexure and uptilting before this submergence. In Minnesota the underlying beds are almost vertical, nearly everywhere, and the Taconic beds dip at angles generally less than 30°. It can hardly be supposed that throughout so great an area the subjacent strata could by any transformation be placed in verticality beneath the Taconic since the deposition of the latter, without equally disturbing the Taconic also. Indeed when such rupturing of the strata, since the deposit of the Taconic, has been observed, as in the region between Ogishke Muncie lake and Gabemichigama lake, the disturbance has involved the Taconic rocks also, and has turned them into various and excessive dip. Such exhibitions, however, are exceptional, so far as observations already made in Minnesota indicate. The Taconic strata maintain, both in Minnesota and Wisconsin, as in the Mesabi and Gogebic-Penokee ranges, a regularity of dip and strike, and a low angle of inclination which are not seen in any of the older rocks.

There is a conglomerate at the base of the Taconic. This is a fragmental, sedimentary conglomerate, embracing numerous rounded fragments from the earlier formations of the region. The lowest stratum seen in the Huronian, in the region north of lake Huron, is reputed to be a quartzyte which varies to a quartzose conglomerate, and by the accession of organic matter assumes a dark color, becoming a "slate conglomerate." In the latter form it has a wonderful development, both in Canada and in Minnesota*. It is the Ogishke conglomerate, of the Minnesota reports. It seems to be the Missasaugui quartzyte and the slaty conglomerate of the original Huronian area. This conglomerate is followed by an immense thickness of dark slaty

* On the passage of the quartzose condition into the slaty, each being pebbly, see Logan 1863, Geology of Canada, pp. 55, 56, 594.

rocks, often cherty, or flinty, frequently very dark-colored, generally siliceous, alternating with thin quartzytes, and grayish feldspathic quartzytes, all in conformable stratification, as a whole. Variously interbedded with these slates and quartzytes, from bottom to top, are beds of basic eruptive rock, and it is necessary to suppose that such eruptions must have been accompanied, in some places, by extensive disturbance and metamorphism. As a group, however, the Taconic strata sustain a uniformity of lithology, within allowable limits of variation, which marks them as one great series, which experienced essentially the same history over very extensive parts of America, and in that respect they show the same individuality as the Keewatin and the Vermilion, which names cover respectively the subcrystalline (earthy) and the crystalline schists of the Northwest. The Taconic is essentially the Olenellus group of strata of the primordial.

The iron ores of the Taconic. The Taconic is the chief iron-bearing formation of the Northwest. It is the "Huronian" iron-group of the Marquette region, the Penokee-Gogebic range in Wisconsin, and the non-titanic ores of the Mesabi range in Minnesota. The writer is not familiar with the Menominee iron district in Michigan and Wisconsin, but the described characters and the parallelisms that have been claimed of the Menominee rocks by Brooks, Rominger and Irving, with those at Negaunee, sufficiently show that, as claimed by Emmons and Houghton in 1846, the Menominee rocks are also of the Taconic.* The numerous important iron-ore deposits that have long been known, and formerly extensively exploited in eastern New York and western Vermont, Massachusetts and Connecticut, embracing hematite and limonite, often manganesic, afford parallels with the iron-ore deposits of the Northwest that are here classed in the Taconic. Some of the descriptions of the ore-pits of Washington, St. Lawrence and Dutchess counties, of eastern New York, recorded by Mather and Emmons in their reports on the geology of those counties are applicable, in many respects, to those of the Penokee-Gogebic and the Mesabi ranges in the Northwest.

The Granular Quartz. As used here the term Taconic does not embrace the "Granular Quartz," of Emmons, as there is sufficient evidence, in the writer's opinion, for making that the par-

*Agriculture of New York, 1846, Vol. I, p. 101.

allel of the true Potsdam of New York state.* The chief reasons for this separation may be given.

(a) *The stratigraphic relations of the Granular Quartz and the Potsdam of N. Y. are the same.* In the first place they are seen to lie unconformably on the older "granite," one on the west flank of the Green mountains, and the other on the northern and eastern flanks of the Adirondacks; and in the second place they bear the same relation to the Red sandrock of Vermont. By Dr. Emmons the Red sandrock was regarded the equivalent of the Potsdam and Calciferous sandrock, but it is described by the Canadian and Vermont geologists as Potsdam. Emmons, Logan, Hitchcock and Marcou agree in making it unconformable on the underlying slates,† but Mr. Walcott fails to find the unconformity at the point described by Marcou.‡

It seems, however, that the preponderance of evidence is in favor of such unconformity, especially when it is further considered in its agreement with observations supposed to be at the same stratigraphic horizon in the Northwest and in the Black Hills. The Potsdam is therefore here the Red sandrock, and unconformable on older slates. But by the discovery of the same fauna in the Granular Quartz and in the Red sandrock Mr. Walcott has shown that these are stratigraphically the same formation. Therefore the Granular Quartz must lie unconformably on other terranes than the "Primary" of the Green mountains.

(b) *While the fossils of the Granular Quartz are cognate with those of the Red sandrock, they are also cognate with all that have been found in the true Potsdam.* They are, however, essentially different from those of the so-called Potsdam of the Mississippi valley. This need not be amplified. It is based on one of the cardinal distinctions that subdivide the primordial fauna.

(c) *The Red sandrock overlying the Georgia group unconformably, as already stated, the Granular Quartz and the Potsdam must have the same stratigraphic position.* While this has not been observed in New York and Vermont (or when so seen the overlying strata were considered to belong to the Red sandrock) it has been observed to be the relation subsisting between an identical quartzyte in the area of the original Huronian, in northern

* Bull. No. 30, U. S. Geol. Sur. p. 18.

† Geology of Vermont, Vol. I, pp. 260, 317. The Taconic of Georgia and the report on the geology of Vermont, *Mem. Boston Soc. Nat. Hist., Vol. IV.*

‡ American Geologist, March, 1888. A great primordial quartzyte.

Michigan, and in northeastern Minnesota, and a series of slates underlying. In other words; The Thessalon quartzyte of the Huronian overlies (probably) unconformably the Plummer argillytes. The Pewabic quartzyte and the Wanswaugoning quartzyte overlie the Animike in northern Minnesota, but the exact contact has not yet been observed; while in the Marquette region the "quartzyte group" of Rominger overlies unconformably his "iron group."*

If we carry the comparison further:—

(d) *The stratigraphic relations of the Granular Quartz and Potsdam to the "granite" are the same as those of a great primordial quartzyte of the Northwest to the "granite."* This western quartzyte has been designated, not only Potsdam, but Sioux quartzyte, Baraboo quartzyte, New Ulm quartzyte, Barron county quartzyte, Wanswaugoning quartzyte, as well as Pewabic quartzyte, and in numerous instances it has been observed to lie unconformably on the granite supposed to be of Laurentian age.

This comparison could be extended to include the Black Hills of Dakota and the primordial section of Nevada, and it would appear that the relations here pointed out for this quartzyte are of wide application and mark it as a formation of continental extent.

(e) By Mather, Rogers, and others who have opposed the Taconic system the Granular Quartz was referred to the Potsdam sandstone.

These considerations seem to justify the conclusion that, contrary to the opinion of Dr. Emmons, the Granular Quartz should be placed at the top instead of at the bottom of the Taconic system, and that the Taconic black slate underlies it unconformably. This does not disturb his general idea that the Taconic is a sub-Potsdam formation, even using the term Potsdam in its original sense as here defined. It is, furthermore, in accordance with the views of the Swedish geologists to find the quartzyte (Paradoxides) horizon, lying above the Olenellus beds, and indicates that the Braintree (Mass.) quartzytes overlie the Braintree slates.

[NOTE.—The only intimation that the writer has been able to find that the Granular Quartz and the Red sandrock had ever been regarded the same formation by the early geologists is a statement in the "Geology of Vermont," Vol. I, 1861 (issued in 1862, Walcott), p. 346. It is by Dr. Edward Hitchcock, and in the following words: "A narrow strip of impure limestone partially sepa-

*Sixteenth report of the Minnesota survey, pp. 45, 46.

rates the quartz rock from the Red sandrock in Monkton. The limestone gradually thins out, and is finally lost, so that the quartz rock and the sandrock unite with each other; and probably the line of junction is only a line separating different degrees of metamorphic action upon the same formation;" but by different geologists both the Potsdam and the Granular Quartz have, on what seemed good evidence, at different times been regarded as the equivalent of the Red sandrock. Some confusion has arisen, as it seems, in the use of the word Potsdam, by the geologists who have examined the Champlain valley in the same manner as in the Mississippi valley.* Some have applied the term to the great quartzyte (the "Granular Quartz" in its different positions) and some to the later, looser sandrock, and Calciferous sandrock, that lie unconformably on the quartzyte, and some to both varieties. The former is the horizon of the Paradoxides fauna, from New England to Minnesota, and the latter is the horizon of the Dicellocephalus fauna. It will require a re-examination of the "sandstone of Potsdam," at the typical locality, to determine the question — which is the true Potsdam sandstone?]

The age of the Potsdam.

Equivalent names. Under this heading are included here several local designations which have been applied by geologists to a formation that extends widely over the United States and Canada, the uniform characters of which, as well as its fossils and stratigraphy, indicate that they all belong to one great quartzyte horizon. Some of these various names are: Granular Quartz, Red sandrock, Thessalon quartzyte (of the original Huronian), Teal lake quartzyte, No. 3, or quartzyte group (of Dr. Rominger), Baraboo quartzyte, Wanswaugoning quartzyte, Pewabic quartzyte, Sioux quartzyte. Further east, it may be represented by the quartzyte at Braintree, Mass., and the Paradoxides beds of Newfoundland. Further west it seems to exist in the Mt. Stephen section, and contains the fauna of the Bow River group, and of the "Prospect Mountain" quartzyte. It is unquestionably found in the Black Hills, but fortunately it has not there received a special name, but is embraced under the term Potsdam. This is essentially the horizon of the Paradoxides strata of the primordial.

Unconformable on the Taconic. It has been stated that this quartzyte is unconformable on the Taconic. This is sufficiently established in Vermont, in Michigan, Wisconsin and in the

* Emmons noticed the difference of lithology, but not the unconformity of stratification. *Geol. of N. Y.*, Vol. II, 1842, p. 269.

Dr. Edward Hitchcock seems to have figured this unconformity in Vol. I, p. 265, of the *Geology of Vermont*, but he considered the "quartz rock" here to belong to the Laurentian. At Chazy Mr. Jules Marcou states that he observed an unconformity between the Potsdam and the Chazy strata, the divergence of dip being 15 degrees.—*The Taconic system and its position in stratigraphic geology*. Proc. Am. Acad. Arts & Sci., Vol. XII, p. 190.

Black Hills of South Dakota. It is presumably so in the area of the original Huronian.* Such a widespread non-conformity indicates that the Taconic was closed by a widespread epoch of disturbance. Since the Potsdam is carried over the edges of the Taconic, and in many places is brought into contact with the "granite," which may be supposed to be older than either, it is evident that this disturbance was followed by a still further inroad of the oceanic waters on the land area of the continent. This submergence has effectually hid the Taconic formation from sight over very extensive areas, and led the geologists who saw the Potsdam lying on the Primary, in New York, to question the possibility of a formation several thousand feet in thickness belonging between them. It also produced a conglomeritic composition in the bottom of the Potsdam at nearly all places where the bottom beds have been seen.

Further evidence of disturbance during the Potsdam. The gradual or paroxysmal sinking of portions of the continent below the ocean during the Potsdam age was accompanied by other evidences of disturbance that have remained undeniable witnesses to this day. There were both basic and acid eruptions of great volumes of molten rock, which in some cases were interbedded in the Potsdam, and in others are found overlying it. These molten rocks are found generally to lie on the Taconic and the Potsdam both, but their date of outflow is fixed later than the beginning of the Potsdam by their stratigraphic relation to the Potsdam. Beds of gabbro are evenly spread with quartzyte strata above and below them, in the Pewabic quartzyte in northeastern Minnesota. In general the gabbro lies on the Animike (Taconic) in Minnesota, but a favorable observation made at Chub (Akeley) lake† demonstrates that this quartzyte was partially deposited over the Animike before the great gabbro flood occurred. The usual immediate overlie of the gabbro on the beds of the Taconic, is due to the fact that those beds were nearer adjacent at the points of issue of the molten rock. It also lies on the Keewatin as well as on the Laurentian; while the Potsdam is overwhelmed and nearly lost by the great mass of lava that issued from the interior of the earth during the time of its deposition. While the gabbro outflow seems to have been the most voluminous and remarkable in Minnesota, and to have been the

* In the St. Louis valley, near Thomson, the basal conglomerate of the Potsdam is unconformable on the Thomson (Taconic) slates. Tenth Minnesota report, p. 83.

† Sixteenth report, pp. 85 and 87.

earliest of the basic Potsdam eruptions, in the area of the original Huronian the Thessalon quartzyte is generally cut by and buried under an eruptive of a slightly different kind, more resembling some of the "traps" of the later epoch. There is reason to suppose this may be due to one of two causes. 1st. That at the time of the gabbro flood in other regions the area of the original Huronian was exempt (or nearly so)* from eruptive disturbance, and that the later basic outflows took place there after the region was elevated above the ocean; or 2nd. That while typical gabbro rock was being extravasated in Minnesota, and in some other portions of the country, a slightly different basic eruption was taking place in the area of the original Huronian. From the fact that some gabbro rock is found in the region of the original Huronian, it appears that the former of these hypotheses is more probably correct, and that there as well as in northeastern Minnesota, the basic diabase and finer trap-rock characteristic of the most of the Kewenawan, were of somewhat later date than the gabbro. That these darker, diabase traps issued at some date after the gabbro flood, is evinced not only by the dikes of the former that cut the latter, but also by the remarkable puddingstones of gabbro that are formed by the inclosure of isolated, transported masses within the diabasic sheets,† seen in the vicinity of Beaver Bay.

This basic eruption characterizes this geological horizon throughout its extent in Minnesota, but toward the east it seems not to have been so characteristic. It prevailed in some parts of Canada‡, and disturbances in the so-called "Quebec group" appear to involve this horizon of rocks. The Adirondack region has not been examined except about its margin. It is believed that this quartzyte exists in many places involved with the gabbro rocks of those hills. Its outcrops about the flanks of these hills have been described at places where most accessible and named Potsdam sandstone. These descriptions are applicable to this quartzyte in Minnesota—even to the vitrified surfaces that are so common in the west,§ and which are not known to

*One small knob of gabbro was seen near Otter Tail village. Compare 16th report, p. 29.

† Norwood, in Owen's report on Iowa, Wisconsin and Minnesota, p. 366; also Ninth Rep. Minn. Sur., pp. 30-31; Tenth Rep. Minn. Sur., pp. 112-113.

‡ Geology of Canada, 1863, p. 483, 865, 875, 879; Geology of New York, 1843, Mather. Part I, p. 444.

§ Geology of Minnesota, Vol. II, 1888, page 516, foot note. Geology of New York; Second district, Emmons; p. 269.

have been seen on any other formation though exposed in similar circumstances.

Post-gabbro eruptions of the Potsdam age. It has been difficult to affirm, until recently, the age of the gabbro outflow. It has generally been considered to have followed the Animike (Taconic) but that it was later than the commencement of the Potsdam was not known to the writer till he made the observations referred to above.* What were the relations of the later basic eruptions of the "Kewenawan" to the gabbro has been described by Prof. Irving and by numerous other observers. There is no reason to affirm a long lapse of time between them, sufficient to allow the formation of an oceanic terrane requiring special designation. The later eruptive rock embraced and probably transported loosened masses from the gabbro, as evinced in the "feldspar masses" described by Norwood near Beaver Bay on the north shore of lake Superior, and the puddingstones observed by the writer. But this, rather than indicating a long intervening time, seems to imply a quick succession in the eruptions, or else a continued elevation above the sea so as to prevent the accumulation of intervening sediments. That there was no exemption from sedimentation after the gabbro is shown by, (1) the absence of any sign of ancient land surface, (2) by the continued and frequent interbedding of eruptive and sedimentary rocks through the entire Kewenawan (Geol. of Wis. Vol. III, p. 403), and (3) by the gradual transition of the basal conglomerate of the Potsdam, in favorable places, from a siliceous, or pebbly-quartzose, character, through a siliceous sandrock to a feldspathic sandrock, and to a pebbly volcanic tuff. Such transitions are frequent on the north shore of lake Superior. One of the most important observations was recorded in 1879,† when the basal quartzose conglomerate of the Potsdam was found, dipping in consonance with the shales and tufaceous conglomerates of the overlying Kewenawan, in the St. Louis valley, unconformable over the Thomson slates, and embracing lenticular spots of shaly rock and red (Kewenawan) conglomerate as constituent and conformable parts of itself. This shows a conformable, though somewhat intermittent, course of sedimentation from the basal conglomerate into the typical detritus of the overlying beds of the Kewenawan; the interruptions and the changes in the nature of the sedimentation being attributable to

*Sixteenth annual report, pp. 85 and 88.

†Tenth report, pp. 11, 32, 33.

the eruptive disturbances that took place in the adjoining regions. It will be seen at once that this links the Kewenawan to the gabbro, and both to the Potsdam.

Acid eruptions during the Potsdam. The dynamic forces that operated to bring molten basic rock to the surface of the earth in northeastern Minnesota also softened the acidic strata of the super-crust, which in some places seems to have culminated in the molten protrusions and lateral displacements of large masses. These acid eruptions, ranging from felsitic to granitic, are of limited amounts in Minnesota and Wisconsin. Sometimes they are in contact with the Taconic strata as at Duluth (10th Rep. p. 108), sometimes with the Potsdam,* and sometimes with the basic eruptions of the Potsdam.† They are seen in contact with the Taconic slates of the original Huronian (16th Report), and there seem to be the direct result of change from some sedimentary, siliceous strata.

Whether this feature of the Potsdam is persistent through eastern Canada, and in New England, is uncertain, owing to the prevalence of definite "Laurentian" theories as to the age of most of the granitic rock that geologists have studied in that part of the country. There is, however, every reason to affirm a widespread and profound volcanic disturbance, extending from the Black Hills, at least, to Vermont and eastern Canada, that began in the Potsdam era and closed with that era, and that some of its results in the forms of acid as well as basic eruptive rock, as mentioned above for the Northwest, must characterize this formation in New England, there is good reason to expect. Indeed some descriptions of such phenomena have been published. Dr. Hitchcock mentions some Potsdam schists that contain "veins of granite whose feldspar is labradorite" (Geol. of Vermont, Vol. I, p. 264). There are many instances published where the slates of the Taconic including the granular quartz are so placed as to run beneath masses of granitic rock, but such a possibility has been negatived promptly by resort to that easy hypothesis of a fault, to bring up the "Laurentian." Dr. Emmons describes such instances.‡ Similar facts have been mentioned by Prof. C. H. Hitchcock§ in New Hampshire,

*Geology of Wisconsin, Vol. II, pp. 251, 506, 522.

†Tenth Minnesota report, p. 110.

‡Geology of New York: Second district, 1842, pp. 141, 145, 159. Agriculture of New York 1846, Vol. I, pp. 63, 94.

§American Geologist, April, 1889, p. 254. Geology of New Hampshire.

although there is no certainty that the slates described by him are of the age of the Taconic. Prof. Hitchcock makes it very apparent that the granites of New England cannot all be placed in the Laurentian any more than they can in Minnesota.

The Potsdam age closed, therefore, with the cessation of the disturbances and volcanic eruptions which introduced it. The beds that were formed were left in upturned and fractured attitudes for the attacks of the succeeding St. Croix age. These strata embraced not only the basal quartzyte of the Potsdam, but the gabbro, and all the succeeding eruptions that are found in the Keweenawan. Here would necessarily appear a marked and extended plane of unconformity, and this fact, when sufficiently recognized, will be found to distinguish the rocks at many places — whether Potsdam or St. Croix — and be a criterion by which to judge of their stratigraphic place in the geological column. In other words, the Potsdam is unconformable on the older gneiss and slates and schists, and is cut and covered by eruptions of the same age as itself. It would not normally be found unconformable on rocks of its own age over wide areas, although contemporaneous disturbance might certainly produce local non-conformity. The later formations may show non-conformity over wide areas of the rocks of the Potsdam, and such we find to be the fact.

The age of the St. Croix sandstone.

That it may be made plain to the reader just what strata are considered by the writer the Potsdam sandstone, this history may be carried one step further. This is the more necessary inasmuch as some of the steps in the history which are well known in the Northwest, have not yet been recognized, or have not been admitted as facts, by most of those who have examined the geology of the Champlain valley. It appears that a very widespread succession of physical changes affected the lower paleozoic and crystalline terranes in America with a uniformity of effect that is surprising, and which leads to very serious questioning of the doctrine that formations can not be recognized by their lithology from place to place because of the liability to physical change. There is, in fact, a remarkable persistence of lithologic characters, and of stratigraphic relationship, between Minnesota and New England. The satisfactory establishment of some points in the geology of the Northwest throws much light on moot points in the geology of the east. While most of these

coincidences and identities have to be reserved to a later discussion, one of the most interesting concerns immediately the formation which is under consideration — the *St. Croix sandstone* of the Mississippi valley, and its relation to the Potsdam.

The separateness of the St. Croix from the Potsdam. It has already been stated that some confusion has been introduced by the use of the term Potsdam by different writers in different senses. This began with the early descriptions of the geology of eastern New York, Vermont and Canada. This confusion was one of the most obtrusive problems that confronted the writer in 1872 in the preparation of his first annual report. In order that a more definite understanding might attach to whatever he should be called on to publish respecting this horizon he chose to designate the lower formation Potsdam and the upper one St. Croix, and this distinction has been observed in the later publications. If not correct it has at least served to give definiteness to all his descriptions.

This problem was given pointedness a short time prior to the beginning of the Minnesota survey by the writings of Prof. R. D. Irving, who had shown that in Wisconsin the upper formasion was unconformable on the lower.* Irving's papers on the Wisconsin quartzytes proved the existence of two formations in places where hitherto, by some, there had been supposed to be but one, and, assuming the upper, or horizontal, beds to be the Potsdam, based on the conjectures of Prof. James Hall published in the Sixteenth (N. Y.) Regents' report, he announced the upper one to be the equivalent of the New York formation and the lower one he relegated to the "Huronian," that convenient limbo to which it has been customary to consign uncertain stragglers from the upper "Silurian" and from the nether "Laurentian." It was not presumed at that time that the geology of the Northwest would be found to tally closely with that of New York, and as there was no mention of such a great "Huronian" quartzyte there, nor in New England, the presumption was that the "Huronian" was a formation that affected Canada and the Northwest, and that, therefore, this great northwestern quartzyte would not be found further east than the northern shore of lake Huron. Only the "Potsdam" was described in eastern New York.

Upon pushing the distinction further east, however, and upon making a wide study of the older terranes, which, when better

* Am. Jour. Sci., Feb., 1872; April, 1872.

understood, are found to exhibit a surprising concord of essential features with those of more eastern as well as western regions, it is found that there is every reason to believe, not only that there exists the same great underlying quartzyte in New England and eastern New York, but that there are unmistakable evidences of the same non-conformity between it and the overlying horizontal, or nearly horizontal, beds. Moreover, it is equally plain, on making an examination of descriptions that have been published by the eastern geologists, that both the formations have been with great positiveness called Potsdam sandstone. It is very evident that no little misunderstanding has resulted from a failure to observe and acknowledge this important line of non-conformity. But wherever it has confronted the geologist in Vermont or eastern New York, it has been glided over indifferently or has been accounted for by some outre hypothesis, such as "overturn" or "fault," or temporary "non-deposition," or "metamorphism from contact with the Primary."

In order to support this statement some references will be made to the published descriptions of the "Potsdam" in New York. No reference will be made to the Granular Quartz nor the Red sandstone, both of which the writer believes, as the reader will have observed, are identically and only, the Potsdam formation; but to some statements concerning the "Potsdam sandstone" as understood by the geologists who made them.

Emmons. In his report on the geology of the Second District, 1842, Dr. Emmons uses these words in describing the Potsdam in Essex county—"In consequence of this rock presenting two quite distinct varieties, and those varieties being well developed, the one at Potsdam, St. Lawrence county, and the other at Keeseville, I have sometimes given it a compound name—the *Potsdam and Keeseville sandstone;* for the reason that at the former place a beautiful granular variety, and at the latter a harder and more crystalline mass predominates, which resembles the granular quartz of the Taconic system." Near Keeseville the rock that outcrops he describes as exhibiting some interesting changes upon the surface of the layers, presenting "a smooth and semi-vitreous surface—a kind of glazing;" by which he seems to have meant the same polished or glazed surface that appears frequently on the Potsdam in Minnesota. It is plain, therefore, that Emmons noted the contrasting lithology, but, so far as the

writer has observed, he did not recognize any unconformity in the "Potsdam," or between it and the Calciferous.

E. Hitchcock. There is not much doubt that Dr. Hitchcock noted exactly an unconformity between the two formations at West Haven (Geol. Vermont, Vol. I, p. 265), but he regarded the lower one as a part of the "Laurentian," and the upper as the Potsdam. He states that "the only way of distinguishing the Laurentian character of the [lower] deposit is by the higher dip of its strata, upon which the Potsdam sandstone rests unconformably. A section passing across the south end of West Haven, in fig. 168, represents the unconformable relations of the Laurentian rocks and the Potsdam sandstone to each other. Were it not for this discordance in the stratification we should regard the lower rock as Silurian because it does not differ lithologically from the sandstone above. But in following the strata northwardly the quartz rock becomes more gneissoid. Some of the specimens in the cabinet are very distinct gneiss, one of them with the labradorite, the characteristic species of the feldspar of the Laurentian series."

Let the reader compare the description of the "quartz rocks" of the Laurentian with the following description of the "Potsdam" *at the same place.*

"The third variety very closely resembles the Laurentian gneiss. It seems to pass into it by insensible gradations. The specimens obtained are from the southwest part of West Haven. All the constituents of this rock are very small, and occasionally the feldspar or the mica may be wanting * * * Associated with these crystalline schists are veins of granite, whose feldspar is labradorite. This mineral is mostly confined to rocks below the Silurian system; and in West Haven it extends only a few feet into the base of the Silurian, and that in small veins from three to ten inches wide.

"The unconformability of the dip of this rock to the Laurentian beneath [sic] may be seen at the extreme southern point of West Haven. Upon the lake, opposite the termination of the railroad the dip of the older rock is 36° East, and only a few rods east the dip of the sandstone is only 9° East. As the south part of West Haven terminates in a cliff this section can be seen distinctly from quite a distance. The rock with the greater dip is as distinctly quartz rock as the other, and there is also a large ledge of quartz rock upon the west side of lake Champlain with the same inclination. Hence the sudden change in the dip

is to be regarded as a safer distinction between the Silurian and Laurentian series than a difference in lithological character."

Setting aside Dr. Hitchcock's identification, either of the following interpretations of the facts, in the light of what has since been learned of the geology of the Taconic and the granular quartz, would be possible. (1) The lower rock is the Potsdam (granular quartz) and the upper is the St. Croix; or (2) The supposed unconformity is only an illusive appearance in the same formation, perhaps false bedding, or oblique stratification, or a sheeted disintegration which sometimes is superinduced by weathering even in the firmest crystalline rocks. In the light of further considerations the latter explanation seems most probable.

(a) Prof. C. B. Adams had stated in his first annual report that the Potsdam sandstone only reached within half a mile of the state line near Whitehall, and did not enumerate it at all in his table of Vermont formations.* If this were true it would be necessary to consider this West Haven quartzyte as the Red sandrock or the granular quartz. Either of these explanations, to so strong an opponent of the Taconic as Hitchcock was at that time,† would be avoided if possible. For, to class it as a part of the Red sandrock spur that shoots southward from the town of Monkton, the last remnant of which his map represents on the south line of Orwell, bearing in a direction toward West Haven, only seventeen miles distant, would be to bring the "Medina sandstone" below the Calciferous which exists in the immediate vicinity and into contact with the Laurentian; which would necessitate the abandonment of the "metamorphic" idea that the Red sandrock and all the Taconic rocks were changed conditions of the Lower and Upper Silurian of the Champlain system of New York. Also, to admit that it is an outcrop of the Granular Quartz of Dr. Emmons, would in like manner bring the Granular Quartz beneath the Calciferous and even unconformably beneath another sandstone that might be the Potsdam; this would substantially confirm everything that Emmons claimed for his Taconic. These alternatives were clumsily obviated by introducing the Laurentian. That this "Laurentian" is the gabbro of the Potsdam age is probable from the nature of the feldspar which it is said to contain.

*First annual report, Geology of Vermont, 1845, p. 61.

†It is evident that a change of opinion was accomplished in Dr. Hitchcock's mind during the preparations of this report. This is intimated in Vol. I, p. 435.

W. W. Mather. So far as discoverable all the descriptions of Potsdam by Prof. Mather* apply to the lower or quartzyte division. He notes repeatedly his belief that the Granular Quartz is a metamorphic condition of the Potsdam.

L. Vanuxem distinctly mentions the same varieties of rock in the Potsdam as Dr. Emmons, and employs the double designation "Potsdam and Keeseville sandstone," but he mentions no unconformity. He intimates, however, that the Potsdam, in its loose-textured variety, is with difficulty distinguished from the Calciferous sandrock. The latter he describes at numerous places in immediate contact on the primary.

Sir Wm. Logan. In the *Geology of Canada*, 1863, this formation is amplified into "Potsdam group," and includes a thickness, on the St. Lawrence river, of 540 feet. This group embraces not only the true Potsdam but several beds of conglomerate, white sandstone suitable for glassmaking, fucoidal beds, limestones and a singular breccia like that described by Emmons at Chazy and said to separate the Potsdam from the Calciferous. The fauna which appertains to the upper layers is that characteristic of the Calciferous. It is evident that the true Potsdam is here confounded with the overlying St. Croix-Calciferous, and that the Calciferous is restricted in the words of Logan, essentially, to "a granular magnesian limestone or dolomite, which from its rough weathered surface and slight effervescence with acids may have suggested the name of Calciferous sandrock." In the annual reports the Potsdam had not been recognized about lake Huron; but the lower great quartzyte had been included, along with all the strata equivalent to the Taconic under the term Huronian. His opinion of some quartzyte beds on Murray bay which at first Logan regarded as Potsdam, and which he so described (*Geol. of Can.*, 1863, *p.* 96), he modified by adding a footnote stating that it had been ascertained by Dr. Dawson that "these quartzytes really belong to the Laurentian series."

James Hall. The Potsdam sandstone does not occur in the Fourth District, on which Mr. Hall reported, but he examined it on the north side of lake Ontario, and subsequently on lake Superior and in the Mississippi valley. His general description in the report on the Fourth District is such as would apply to the lower quartzitic portion.

In the lake Superior report of Foster & Whitney (1851) the step which was inaugurated by Logan in the creation of the

*Geology of New York, First District, 1843.

"Potsdam group," embracing the quartzyte and the overlying sandstone in one designation, was completed by the entire severance of the lower formation from the name, and its application only to the upper or nearly incoherent sandstones. At the same time the quartzyte, along with all the strata of the Taconic associated with it, were included in the "Azoic," embracing both the Laurentian and Huronian. This upward movement of the names of the New York formations, is shown by the following words (p. 114): "The Potsdam sandstone of New York is a quartzose rock whose particles are firmly aggregated, while the the same rock, on the northern slope of lake Michigan, is so slightly coherent, that it may be crushed in the hand. The Calciferous sandstone of New York, when traced west, passes into a magnesian limestone." This supposed change in the nature of the formations toward the west is largely imaginary; the change seems to consist rather in the transference of the original names to strata higher in the scale, and the creation of new names for the abandoned strata. All the authors of this report, including Prof. James Hall, apply the name Potsdam only to the friable sandstones which are unconformable with the Copper-bearing traps and basalts which, as already shown, are of the age of the lower quartzyte.

As to the paleontology of the Potsdam in New York, which is quite meagre if the more recent additions from the Calciferous be disregarded, an interesting problem centres on the fossils Lingula (Obolella) prima and (Lingulepis) antiqua. By Prof. Hall these are assigned to the Potsdam. In respect to L. prima it is reported at Keeseville on the authority of Dr. Emmons, and it is reported from the Mississippi valley on the St. Croix river. To the writer the St. Croix beds have been known for some years as belonging about to the horizon of the Calciferous, and they have been so parallelized by Irving.* The Calciferous, here including the magnesian limestone known as Lower Magnesian, is unconformable on the trap rock, and, in common with the sandstone underlying it, becomes conglomeritic by reason of such unconformable contact. The beds here exposed are not so low as the lower layers at Stillwater where the first specimen of Dikellocephalus was discovered by Dr. Owen. It would seem, therefore, if we can depend on the indications of paleontological evidence, that the Potsdam at Keeseville, containing Lingula prima would be considered substantially the parallel of the Calcif-

*U. S. Geol. Sur. Monogr. V. Copper-bearing rock, of lake Superior, p. 446.

erous beds at Taylor's Falls in the St. Croix valley. What are the facts? On re-examining Dr. Emmons' description of the sandstone on the Au Sable river in his report on Essex county, he says that this general range of sandstone, containing the Lingula prima according to Hall, *reposes against the hypersthene rock*, (i. e., the gabbro) and contains Lingula antiqua; and Prof. Hall corrects this indentification of Emmons by saying the species figured by him from this place is not L. antiqua but L. acuminata of Conrad, which is a Calciferous species, and does not occur, to his knowledge, in the Potsdam.* Therefore all the evidence from paleontology and from stratigraphy, so far as it can be gathered from the report of Emmons and the first volume of the Paleontology of New York, indicates that the beds on the St. Croix are the equivalent of those described at Keeseville, and that both belong to the Calciferous; at least that they are both later than the eruptive epoch of the Potsdam as here limited.

This brief examination of some early descriptions of the Potsdam of New York, which might be extended to include several other names, is sufficient to prove the truth of the foregoing statement that the distinction which has been made in the Northwest could with propriety also be made in the East, and that a plane of non-conformity between the Potsdam and the Calciferous extends through eastern New York and Vermont, and that there, as in Minnesota, the upper (St. Croix) sandstone has greater affiliations with the strata that succeeded the break than with those that preceded it.

In this review it is assumed that the "sandstone at Potsdam" preceded this non-conformity. It is evident that some re-examination should be made of the region before this can be considered established. Dr. Emmons, in his section passing from Canton to Parishville (Plate ix. *Geol. of New York*) shows that *gneiss* exists at Potsdam below the sandrock, and this rock he always keeps definitely distinct from *hypersthene rock*, which he argues was elevated at a later date than the Green mountains. The parallelism of position between the Potsdam sandstone at Potsdam, and the Granular Quartz, in this respect, both lying upon the gneiss, not only indicates a possible parallelism of age, but that they are possibly older than the Keeseville sandstone which rests against the hypersthene rock.

It is further assumed, in this review, at least in making the

*It is put in the "Potsdam group" by Logan, Geol. of Can., 1863, p. 102.

extension of the western parallels to the east, that the gabbro of the Northwest is the chronologic analogue of the hypersthene rock of the Adirondacks. The lithology is identical, except that various "limestones" are mingled with the hypersthene rock which have not, so far as known, any parallels in the gabbro of the Northwest. This assumed parallelism may also be set down as not sufficiently established.

It is also assumed that the Pewabic quartzyte of northeastern Minnesota, with which gabbro is interbedded and which lies below the great gabbro overflow, is the equivalent of the Wauswaugoning quartzyte and of the Pipestone quartzyte of the southwestern part of the state carrying a primordial fauna, which last is very certainly the equivalent of the Thessalon quartzyte of the original Huronian. Still the Pewabic quartzyte may not hold this relation to the Wauswaugoning beds; the connection has not been traced; yet they seem to be similarly situated with respect to the gabbro sheet, and are not widely separated from each other.

The writer has attempted to indicate such general equivalency as has appeared to him probable, and which embraces a greater fund of concordant fact and testimony than any other scheme of chronologic succession. He may be wrong in some parts of this history, and especially in the extension of the story as made out in Minnesota to eastern states, and holds it, in large measure, as tentative at this stage of the investigation. When facts can be found out sufficient to correct it in any way, he will be glad to welcome them, for he freely admits that there are questionable steps and missing links in the history, which have to be bridged by hypothesis and nothing else. That is, however, the nature of all investigation, and especially of all attempts to formulate any general truth.

PROBLEMS THAT NEED FURTHER INVESTIGATION.

As already stated, as this investigation has proceeded, no sooner did we surmount the difficulties which immediately beset the first attempts than new difficulties appeared. The solution of one problem seems to serve for vantage ground to behold others in the greater distance. It will be desirable to mention some of the questions that appear at present to require further study, and further field-work. This will distinguish more exactly the status of our present knowledge, or body of truth on which we rely, from the realm of hypothesis or of unfinished work and

research, to which it will be necessary to devote the efforts of the survey at some future date.

Eruptive and sedimentary Laurentian. Beginning with the Laurentian, as defined above, one of the unfinished courses of study relates to the distinctions, both geographic and structural and petrographic, between the eruptive masses of syenite, or granite, and those that are supposed to have resulted from change *in situ* of the oldest sediments. This will involve the further question whether the "gneissic structure" is necessary, or even possible, in a truly eruptive rock. But first of all it will necessitate a correct definition of the term "gneissic structure."

There are three distinct ideas that have been confused under the term gneiss, or gneissic structure. No reference is made here to the use of the term gneiss as a rock species, but to the structure which is supposed to distinguish it, the proportionate amounts of the usual mineral ingredients being variable, and sometimes constituting a dark-colored, perhaps basic, rock, and at other times an acidic one. Referring only to *structure*, therefore, a rock has been said to be gneissic when *foliated;* but it is plain that there may be different kinds of foliation, (a) that lamination which consists of an undulating layered structure, the mica element not being unevenly distributed, but all the scales being parallel with the sheeting, and all the grain of the rock having a uniform structural rift which facilitates quarrying. If there be a finer lining or sheeting of the mica element the lines or sheets are not continuous far, and may be seen to fade out within a distance of a foot or two. That is to say this foliation does not indicate a profound separation of the minerals of the rock into layers or long continuous sheets. (b) A second sort of foliation is that which arises from a distinct separation of the minerals of the rock, or different proportions of the constituent minerals, into sheets or strata that continue over long distances. Such separation is indicated on the weathered surfaces by color-bands, and by petrographic differences of grain and composition. In short this foliation is plainly a modified sedimentary structure. The sheets, or layers, or strata, into which the rock is separated, are traceable over large surfaces. The crystalline condition of the grain here may be as perfect as in the last, and this constitutes the "crystalline schists;" but in many places there is seen an imperfect, or interrupted, crystallization, the various grains blending round their borders into each other, or being lost in an

indefinite matrix, or developing porphyroidally. (c) Still another structure has been styled gneissic. A massive homogeneous rock, which may have neither of the foregoing kinds of foliation, but which exhibits the micaceous or hornblendic element evenly distributed in isolated individual grains throughout the whole, yet is seen to have a uniform elongation of the separate crystals, of all kinds, in the same direction. This furnishes also a kind of rift or grain which pervades the mass, rendering it easier to break in the direction parallel with the greater diameters of the crystals than in any other, but it is essentially a massive non-foliated rock. A massive structureless granite, or syenite, is rare to see. Hence by far the greater part of the Laurentian, whether eruptive or sedimentary, is properly styled gneiss. It is obvious, however, that these three structures should not all be described by a single term.

When these structures are once sufficiently differentiated in the mind of the observer, and are carefully applied in descriptions, there will still remain to ascertain what relations they separately sustain to the supposed two sorts of Laurentian rocks, i. e. whether one or the other may be found to characterize the actually eruptive acid Laurentian, or the metamorphosed sedimentary Laurentian.

Planes of hydro-thermal fusion, and their relation to the origin of the crystalline schists. A second problem connected with the Laurentian, and which appears prominently in the horizon of future research, relates to the origin of the crystalline schists.

It has been stated above that there is every evidence to suppose that the eruptive epoch which introduced the Vermilion age (i. e. the crystalline schists) continued into the Kewatin (i. e. the sericitic schists and graywackes) by an unbroken and uniform succession of events and oceanic deposits. This binds the Vermilion and the Kewatin, historically, closely together. It has been said also that the mineral characters of the Vermilion fade out very slowly into those of the Kewatin, but that when fully established the change is so great that the formations have great mineralogical contrasts. In other places the crystalline schists have a very feeble development at the horizon where they would be expected to appear, and the Kewatin graywacke-like sediments pass into the Laurentian sediments through a gradual change from graywacke to gneiss—a gneiss having the second kind of foliation described above.

The crystalline schists seem to be, nearly always, as completely crystalline as the gneiss. If the origin of the basic sediments of the crystalline schists be akin to that of the sericitic sediments of the Kewatin, viz. from volcanic ejectamenta, the query quickly arises—why are they not similar in the resulting rocks? Why are the crystalline schists so uniformly composed of the same minerals as make up gneiss, though differing from gneiss in the relative amounts of those minerals and in the evident sedimentary structure, while the Kewatin, sericitic schists are only subcrystalline and are often earthy? Is it not plausible to suppose that the crystalline schists are but a phase of the earthy Kewatin schists, due to the encroachment of hydro-thermal fusion-planes upon them? At the present time these beds all stand nearly vertical. If this fusion affected them after this verticality was attained, it may be supposed that the approach of the fusion-plane toward the surface of the earth would be nearer in some places than in others. When the fusion was accompanied by fracture more or less of the fused rock-matter would be thrust through the fissures and would appear as eruptive rock. Since there are certainly places where in the Kewatin sediments such fusion, and even such eruption, seems to have resulted from the Kewatin itself; and since in the immediate vicinity the sediments adjoining take on over a greater or less width, the characters of the crystalline schists, and at other places the crystalline schists do not appear where the Kewatin sediments exhibit that peculiar semi-crystalline condition which has been mentioned as "porphyrel," it has appeared to the writer that very likely the crystalline schists have no constant stratigraphic place, any more than the Laurentian gneiss, and that the "crystalline" phase has been superinduced *in situ* on basic (or acid) sediments in strata of different ages, according as, after being deposited, and even after being tilted to verticality, the level of hydro-thermal fusion was able to reach them or not. Therefore, without any undulating of the actual strata in anticlinal and synclinal folds (a supposition which seems to be precluded in some places by the extensive present vertical position of all the strata), there still might result, superficially, successive belts of rocks of different kinds. The belts would express the effects of hydrothermal fusion, perhaps on the same sort of sediments, in different degrees of intensity. Wherever erosion and denudation may have been sufficient to bring the present surface down to the level where the fusion-plane operated in its full intensity,

there we should find the present surface rock to be gneiss if the sediments were acidic, crystalline schist if the sediments were partially basic and stratiform, or eruptive rock if there were fissures through which such could and did escape. Where the surface erosion has not been sufficient to expose the upward (or the downward) undulations in the plane of perfect fusion, we find the earthy, or volcanic, or siliceous, sediments more nearly in their original condition.

Date of upheaval of the crystalline schists. Intimately connected with the question of the origin of the crystalline schists is the question of their date relative to the epoch of their upheaval, and the further, or prior, question as to the cause of the very general and extensive verticality of all the sedimentary strata that precede the Taconic (Huronian).

Nature and origin of jaspilyte. Attention has been called to some points in the investigation of this question which need further examination.

What is the "muscovado rock?" and, particularly, does it represent a sedimentary formation younger than the Kawishiwin and older than the Taconic.

COMPARISON OF THESE RESULTS WITH THOSE REACHED ELSEWHERE.

Following is a tabulated statement of the general stratigraphy supposed to exist in Minnesota, according to the foregoing sketch.

Calciferous. Magnesian limestones and sandstones....................................... *St. Croix.* Sandstones and shales...........	Dikelocephalus horizon.
Overlap unconformity.	
Potsdam. Quartzyte, gabbro, red granite and Kewenawan...........	Paradoxides horizon.
Overlap unconformity.	
Taconic. Black and gray slates and quartzytes, iron ore, (Huronian, Animike).......................	Olenellus horizon.
Overlap unconformity.	
Kewatin (including the Kawishiwin or greenstone belt, with its jaspilyte), Sericitic schists and graywackes................. *Vermilion* (Coutchiching), crystalline schists **Eruptive unconformity.** *Laurentian.* Gneiss......	Archean.

Comparing this with the results reached by the late Wisconsin survey, it is found to differ considerably from the table of formations published by Prof. Irving, in the third volume of the final report of that survey, pp. 92 to 211. Prof. Irving describes the Laurentian as composed of "dark-colored and altered (chloritic) hornblende-gneisses and pink quartzose granites." These he considers very evidently originally clastic rocks, without any recognizable eruptive portions, and to lie unconformably below the Huronian. The last he divides into twenty-one parts, in the same manner as major Brooks, in his report on the geology of Michigan. The aggregate thickness is supposed to be about 12,800 feet. But in this thickness he includes all the strata from his Laurentian to his Kewenawan, viz. in descending order:

XXI. Mica schist, with intrusive granite.

XX. Probably mica schist, like XXI.

XIX. Greenstone schist.

XVIII to XV. Alternations of black mica-slate and dark gray quartzyte, or quartz schist.

XIV. Black mica-slate. This and the last are carbonaceous.

XIII. Chloritic dioryte.

XII. Black magnetitic mica-slate.

XI. Probably mica-slates.

X. Mica slate.

IX. Chlorite dioryte.

VIII. Probably mica-slate, like VII.

VII. Mica-slate.

VI. "Peculiar hornblende rock," containing also quartz, apatite, milky orthoclase and rare plagioclase; also biotite, cut by pinkish, coarse, granite veins.

V. Black feldspathic slate, carbonaceous.

IV. The magnetic belt; made up of banded magnetitic quartzyte, magnetitic quartzyte, magnetitic quartz-slate, actinolitic magnetitic quartz-slate, arenaceous to compact and flaky quartzyte, thin-laminated, soft, black, magnetitic slate, hematitic quartzyte, garnetiferous actinolite-schist or eclogite schist, and dioryte.

III. Siliceous slate or schist, a light-gray, soft, mica-schist, sometimes a fine quartzyte.

II. Arenaceous quartzyte.

I. Crystalline limestone.

For greater details respecting these parts the reader is referred to Vol. III, Wisconsin geological report, pp. 106–166.

The Keweenawan system Prof. Irving here describes as consisting of a "lower division, embracing chiefly great flows of gabbro, diabase, and melaphyr, and an upper division composed chiefly of reddish feldspathic sandstone, subordinate to which are heavy beds of boulder-conglomerate, indurated gray and brown quartzless sandstone and black shale." Among its eruptive rocks he includes gabbro, diabase and diabase amygdaloid, melaphyr, granite and porphyry, the last being possibly clastic. Among its fragmental he notes boulder-conglomerate, black and gray shales, gray and brown quartzless sandstone and red sandstone and shale.

Unconformable over the last he places the light-colored "lake Superior or Potsdam sandstone," which he considers either the "equivalent or downward extension of the Potsdam sandstone series of the Mississippi valley."

It is evident that in this description there is included nothing that answers to the Kewatin and Kawishiwin. It appears that a feeble representation of the crystalline schists is noted in connection with the Laurentian, as "dark hornblende gneisses." Essentially all of these parts, from No. I to No. XX inclusive, are the Animike of northeastern Minnesota, the real Huronian without the overlying Thessalon quartzyte. According to observations already recorded this overlying unconformable quartzyte is in northern Minnesota interbedded with gabbro sheets, and the great gabbro flood lies on the lower portions of it. It is a natural inference that in an epoch of successive volcanic eruption like that which followed the gabbro outflow, a quartzyte would locally lose its typical character, and would be converted to feldspathic sandstones, conglomerates and shales, and that these would be interbedded with the eruptive sheets. Such seems to have been the case in northern Wisconsin and in northeastern Minnesota within the area affected by this remarkable series of eruptions. But in central Wisconsin, as well as in southern Minnesota, and in S. Dakota, the normal conditions again prevailed, and a similar quartzyte is found to exist, repeating the sedimentary succession that obtains in the area of the original Huronian.

The peculiar "mica schists" cut by intrusive granite, represented to overlie all the rest of the Huronian, seem not to have been identified in Minnesota. There is, in connection with the

gabbro, in northeastern Minnesota a large amount of red granite, passing to felsyte such as that seen at the *Great Palisades*, on the north shore of lake Superior. It is possible that in connection with this granite will yet be found some micaceous schists answering to these in Wisconsin, the result of metamorphism from some of the Animike beds.

Prof. Charles E. Wright and major T. B. Brooks, who report, in the same volume, on some of the crystalline rocks of Wisconsin, present substantially the same classification. But they distinctly include the "crystalline schists" in the Laurentian. Brooks, who made out this order first in the Marquette region, and gave the parts similar numerical designations, groups them in three principal parts, viz.:

Upper Huronian, Beds XIV to XX.

Mica slates, mica schists, granites and gneisses.

Middle Huronian, Beds VIII to XIII.

Quartzytes, clay slates and obscure soft schists.

Lower Huronian, Beds I to VII.

Quartzyte, marble, iron ore, novaculite.

Brook's stratigraphic scheme is subject to criticism, and is ambiguous and certainly incomplete, although for a pioneer attempt to set the stratigraphy of the region of Marquette into a semblance of chronological succession it deserves great praise, for it supplies the first general classification and gives form to a tangled mass of variant and unfinished observations and isolated facts that had been published before. Since the examinations made by Brooks the whole country has been much cleared up, many new openings have been made and the geology is much easier to ascertain with certainty than ever before. Dr. C. Rominger, in a later survey, was aided by some of these advantages, and in some instances he was enabled to correct the stratigraphic scheme of major Brooks. His report, however, is, as it professes to be, mainly a description of facts, without much effort to decipher the stratigraphy.

Dr. Rominger hesitated about placing the granitic rocks of the Marquette district as the parallel of the Laurentian of Canada, although he regards the rest of the series, with some noteworthy differences, as the Huronian. He rejects the twenty subdivisions made by Brooks, as altogether too numerous and somewhat

vague, and some of them he omits from the succession, regarding them as intrusive masses belonging really to lower horizons. The two quartzyte members, of Brooks, he considers but one. With slight exceptions Dr. Rominger's descriptions and classification are in accord with the general stratigraphy and all the geology of the Northwest as now held by the writer. Those exceptions consist, principally, in dividing the strata concerned into two distinct formations, separated by a plane of unconformity which exists everywhere and is observable (and has also been mentioned many times by him), in the iron regions of both Minnesota and Michigan. Brooks paid but very little attention to the rocks embraced by Rominger in his serpentine and dioritic groups. But these constitute, in accordance with the conclusions of this report, the basement floor on which the true iron-bearing formation makes an unconformable overlap succession, and are the southern representatives of the sericitic and chloritic schists and graywackes of the Kewatin. Another important difference concerns the great quartzyte of the Marquette region. Dr. Rominger considers it a constituent part of the conformable strata of the Huronian. I think sufficient evidence exists for removing it from the system that embraces the ore beds, and placing it as an unconformable overlying stratum, the equivalent, nevertheless, of the great upper quartzyte member of the original Huronian. Again, the arenaceous slate group, and the iron group, appear to the writer to be, if not identical, very closely associated members of the grand series, and not worthy of separate designation. One may overlie the other, in general, but they probably graduate into each other lithologically and stratigraphically.

In making comparisons, however, the most interesting are found to subsist between this work and that of Mr. A. C. Lawson, of the Canadian survey. In the examination of the geology of the Lake of the Woods Mr. Lawson encountered a series of rocks, which, while included by his predecessors in the Huronian, differed markedly from the descriptions of the original rocks of the Huronian as published by the Canadian survey, and he gave them the name which is used by the Minnesota survey,—the "Keewatin." These he inferred to lieun conformably below the Animike, found further southeast, and they were subsequently traced continuously to the north side of Gunflint lake, and found to become there the very same strata which the Minnesota survey had already described as unconformable below the Ani-

mike, but which, however, were not fully wrought out by the Minnesota survey, nor identified as different from the Huronian. In the later prosecution of the work in Minnesota this wide-spread unconformity has been fully recognized, and the separateness of the strata above it from those below has been established beyond all question.

A still further interesting parallel between the work of the Minnesota survey and that of Mr. Lawson consists in the separation of the crystalline schists from the Kewatin, under a distinct name, and the recognition of some (at least local) unconformity due to eruptive action between them and the Laurentian gneiss. Mr. Lawson gave them the name Coutchiching, not including in them the basic eruptive rock associated at this horizon, and this survey, about the same time applied to them the name Vermilion, but included in them all the eruptive basic rock which appeared to grade off into dark and hornblendic schists and to micaceous schists. By Mr. Lawson this eruptive belt is considered as of later date than the schists, and perhaps as late as the Kewenawan, but by the writer it is regarded, so far as seen in Minnesota, as having actually preceded the crystalline schists, and really to be the most obtrusive agent in the introduction of the lithology that characterizes the crystalline schists. The principal eruptive rock was the acid Laurentian gneiss, according to Lawson, but according to this survey it was the basic doleryte.

There are minor differences, such as that touching the eruptive nature of gneisses, the later date of the Laurentian, the character of the thin, interleaved, gneissic strata between thin sheets of mica schists, sometimes reaching 100 or more alternations, and others, which will furnish subjects for future research. But the general concord, in the main results, between the conclusions of Mr. Lawson, and those expressed already, in this report, on the succession of the principal steps in Archean stratigraphy, is certainly a cause of satisfaction, and gives corroborative evidence of the correctness of the conclusions arrived at.

It is not necessary to make comparisons between these results and those of New England geologists. There is not sufficient evidence yet that the New England crystalline rocks can be assigned unexceptionably to the Archean. It has not escaped observation, however, that there are many general concordances. Especially is this true of the report on the New Hampshire crystalline rocks by Prof. C. H. Hitchcock. It is believed by

the writer that the same strata extend, with characteristic lithology, through the Archean terranes of New England, and that they will be identified by and by with all the necessary evidence.

REPORT OF H. V. WINCHELL.

III.

REPORT OF FIELD OBSERVATIONS MADE DURING THE SEASON OF 1888, IN THE IRON REGIONS OF MINNESOTA.

By H. V. Winchell.

The object of this report is simply to place on record the facts observed and noted during the summer of 1888 regarding the geology of the region east of Tower, paying particular attention to the iron ore deposits. During the months of July, August, September and October an attempt was made to visit all the outcrops of iron ore east and south of Ely, for the purpose of making notes, collecting specimens* and learning the relation of the ore to the rocks of the region, as well as its extent and probable value. In many cases reported by explorers and so-called "experts" it was found that their accounts either exaggerated greatly the amount of iron ore to be found at any specified place, or else that there was no iron ore there at all—nothing but iron-rusted rocks or beds of heavy dark dioryte, or even no signs of iron at all.

Region traversed. The first month was spent in examining the magnetic ore belt which lies along the north edge of the gabbro and the south side of the Giant's range. A party consisting of the writer and Mr. W. D. Willard, of the State University, with Indian packers, went overland from Birch lake to the Duluth and Iron Range railroad along the Giant's range, making frequent cross-sections of the rocks and examining all the workings in the magnetite prosecuted there in past years. After returning to Birch lake the same belt of ore was followed northeastwardly into Twp. 63–10 on the Kawishiwi river.

During the remainder of the season the party led by Mr. Uly. S. Grant, assisted by Mr. A. D. Meeds was also engaged on the investigation of the iron ores. A trip southward to lake Superior was taken through an unexplored part of the country, and the various lakes along the route were examined. The parties

*The specimens collected by H. V. Winchell are numbered in pink shellac and alcohol, and have the letter H following the numbers.

then proceeded to Gunflint lake and worked for a month southwestwardly. Mr. Grant's party made two or three extended trips to the south for the purpose of visiting reported iron locations, reaching Brule lake and lake Alice and making notes on the geology of their shores. The other party followed the northern edge of the gabbro to connect with the observations made from Birch lake northeastward, closing by examining some of the jasper and ore beds in the vicinity of Snowbank lake.

All the outcrops of magnetic ore that could be learned of were visited,—with the exception of one or two remote places difficult of access and which were in all probability in the gabbro. Also a great many exposures of hematite were examined and many new facts obtained regarding its occurrence and relations to the surrounding rocks.

The importance assigned by many of the explorers to a small bed of jasper, or jasperoid rock in the crystalline or earthy schists, is often amusing. On the strength of such a discovery they will recommend the purchase of extensive tracts of land and the operation of a diamond drill on the spot or in the vicinity; being certain that the presence of the jasper—not always even *in situ*—is a sure indication of the proximity of a valuable body of ore. They do not seem to realize that jasper is not iron ore and that a mountain of jasper is no sign, in itself, of iron ore any more than of any other mineral.

Another erroneous idea which has gained prevalence is that a bed of ore is sure to improve the farther it is followed toward the center of the earth. The contrary is often true, and it is evident that while the grade of the ore *may* improve and the quantity of it *may* increase with the depth of a shaft, yet there is no reason to expect such a thing. Therefore it is a poor investment to buy land—or rock—which contains a small per cent of iron on top, and base hopes of a paying investment on the expectation of finding it to be high grade ore 50 or 100 feet from the surface.

It is surprising what credit is given by capitalists to any man, who, with no knowledge whatever of mineralogy or geology, and therefore no judge of the probability of finding ore in a certain locality, has, however, the assurance to tell them that there is iron in such and such a place if they will only put in a shaft and "open up the mine." On the strength of such recommendations as these thousands of acres of land have been bought at a high price, which are utterly destitute of iron ore and are,

perhaps, nothing but cedar swamps or hills of bare rock; and in many places there are abandoned pits and machinery where not only shafts but fortunes have been sunk in hasty and profitless prospecting and blasting. The machinery and supplies have been "packed" thither at great expense, and men employed at high wages to dig for iron when a person who is at all acquainted with the geology of the region would have told in a short time that there was no use whatever in spending a cent. In two or three places shafts were seen sunk in greenstone where there was not the slightest indication of iron nor even a bit of jasper to mislead the anxious searcher for wealth; all because it was "on the iron range."

Such hasty, ill-advised proceedings always serve to bring a region, no matter how valuable in reality, into disrepute, and to weaken the confidence of capitalists all over the country who attribute these losses and failures to the wrong cause and are, therefore, deterred from investing their own capital in the really valuable and profitable localities.

But however much money may have been hopelessly squandered in the search for iron in barren regions, yet a great deal has been employed in the development of new and rich iron deposits during the past year. The D. & I. R. R. has been extended 25 miles to Ely, south of Long lake, from which place were shipped 1,200 tons of ore daily for about two months of last season. This ore all came from the Chandler mine, which has put in a fine plant of machinery and hoisting apparatus and will be ready for much larger shipments next year. The Pioneer and Zenith mines will also be in a condition to produce a large amount of high grade ore in 1889. These mines are located east of the Chandler at Ely. At several other places in the same vicinity large crews of men have been at work uncovering and opening up promising deposits of iron ore.

There has also been some attention paid to the Animike magnetite, and in several places around Birch lake shafts and drillings have been made. None of these, however, seem to have met with success, as the ore is not found in paying quantity.

More extensive ore-beds have been found west of Gunflint lake in Twp. 65–4 than elsewhere in this formation. Work will be commenced in this region as soon as railroad facilities can be obtained. In the following notes each of these outcrops and workings is described in detail.

Principal varieties of iron ore. It is well known by those

familiar with the geology of northeastern Minnesota that there are three principal kinds of iron ore. These are found in connection with three different formations. The first kind is red hematite which is found interbedded with jasper in folded and crumpled beds that occur in what has been called the Keewatin formation. This is the ore which has been mined so extensively and is in such demand by the manufacturers of steel using the Bessemer process. Many analyses have been published heretofore. The second kind is a fine-grained glistening magnetite which is generally found in nearly horizontal beds of quartzyte supposed to be a part of the Huronian formation. This is the ore which was first worked before the Vermilion lake ore had been thoroughly tested or investigated. It has not been found in quantities sufficient to pay for mining until quite recently when large beds of it, west of Gunflint lake, have been penetrated by diamond drills. This is a high grade ore and contains no titanium. An analysis of a specimen from N. E. ¼ sec. 23, 60–13 gave the following, according to Mr. C. F. Sidener:

	Per cent.
Silica, SiO_2	11.89
Alumina, Al_2O_3.	.34
Magnetic oxide of iron, Fe_3O_4	87.00
Lime, CaO	.20
Magnesia, MgO	.80
Titanium, Ti	None
Phosphorus, P	.056
Sulphur, S	Traces
	100.246
Metallic iron, Fe	63.07

The third variety of iron ore is also magnetite. It is coarse and has a duller lustre than the Animike ore and is not so strongly magnetic. It is found in many places in the gabbro, which sometimes contains so much of it that it seems to be pure magnetite. This ore almost always contains a large amount of titanic acid which ruins it for merchantable ore, with only present methods of reduction. Immense deposits of this titaniferous ore are found, and most of them have been purchased from the U. S. government in the hope of being able to conduct remunerative mining operations. When a method for reducing titaniferous ores cheaply is discovered such iron ore will be valuable; but until then it is worthless.

An analysis of a sample of this ore from sec. 36, 63–10 as reported by Mr. C. F. Sidener is:

	Per cent.
Silica, SiO_2	11.37
Alumina, Al_2O_3	1.32
Magnetic oxide of iron, Fe_3O_4	53.33
Protoxide of iron, FeO	14.42
Oxide of titanium, TiO_2	16.03
Lime, CaO	.10
Magnesia, MgO	2.73
Phosphorus, P	.01
Sulphur, S	Traces
	99.31
Metallic iron, Fe	49.40

These are the principal kinds of ore. But there are various modifications and combinations of them which would not come strictly under any one of the three heads. There are, for instance, magnetite beds in the Keewatin; sometimes mixed with hematite; sometimes all magnetite. On the other hand there is hematite and even limonite in the Animike; and there are extensive fragments of the Animike formation inclosed in the gabbro which thus appears, on a hasty examination, to contain non-titaniferous, fine-grained magnetite. The gabbro is thus found to be the only rock which always contains the same kind of iron ore—(titaniferous ?) magnetite.

GIANT'S RANGE.

The first work of the season was done, as above stated, on the syenite range south and southwest of Birch lake. The trail which leads from the lake to the Duluth and Iron Range R. R. starts from the sandy bay in sec. 32, 61–12. It runs nearly south for two or three miles after becoming established. It is a poor trail but grows better as the railroad is approached. South from Birch lake the country rises rapidly, and the aneroid indicated a hight of 225 feet at a point a mile and a half from the lake. Ridges composed of drift containing syenite boulders are crossed until in the S. W. ¼ sec. 8, 60–12 a ridge of massive syenite rises quite suddenly over 200 feet more. This is the Giants' range, 480 feet by aneroid above Birch lake. Before reaching the ridge some huge boulders of syenite and dioryte are seen. This ridge is here composed of coarse reddish syenite containing

much blue, chalcedonic quartz in grains one-quarter of an inch in diameter. The pink orthoclase is frequently porphyritic. The hornblende is somewhat decayed in all the specimens observed, probably because they came from near the weathered surface. Samples of this rock are 357.

The drift on the north side of the ridge is reddish and contains many boulders. On the south side of the syenite ridge the land is from 100 to 150 feet lower than the summit of the ridge. Some immense boulders are seen.

At ¼ mile south of the S. E. corner sec. 7, 60–12 there are seen numerous angular fragments of olivinitic magnetite projecting through the moss. These pieces contain thin strata of good iron ore; they seem to lie just on top of the solid rock and to have been moved from their original place by the action of frost. Samples are numbered 358.

The trail leads through a swamp for the next half mile. Just north of the small creek which crosses the line between secs. 17 and 18, 60–12 there is an exposure of solid rock. It lies in strata which dip S. S.E. 10°–12°. The rock is olivinitic and contains considerable magnetite both as a constituent of the rock itself and in veins which coincide nearly with the direction of the bedding. This rock looks much like a quartzyte but contains a large proportion of olivine. Samples from here—S. W. ¼, S. W. ¼ sec. 17, 60–12—are 359. The rock is fine-grained and greenish; it is overlain by a very light covering of drift.

Rock similar to the last is exposed in places as far south as the E. quarter post sec. 19, 60–12. The needle dips about N. 50° over this entire distance.

In the N. E. corner of sec. 19, 60–12 is a shaft about ten feet deep. Indian John Beargrease says it was dug about 14 years ago by Peter Mitchell. After penetrating about five feet of drift the bed rock is encountered. It is the same greenish, olivinitic quartzyte containing magnetite. The needle dips N. 57°. Specimens from here are 360. Some of this rock is slaty; 361.

Another shaft has been made in N. W. ¼ of N. E. ¼ sec. 19, 60–12. The rock here is quite similar to the last; some of it is very thin-bedded. A sample from this shaft showing fine stratification is 362. There is very little good ore visible here, though the needle dips 90°.

A smoothed, black exposure of ferruginous quartzyte several acres in extent, appears on the surface of the ground in the N. W. ¼ of N. E. ¼ sec. 19, 60–12. The rock and magnetite both

weather shiny black, and the metallic lustre gives one the idea that he is standing on a hill of pure iron. Sample of good ore from here is 363.

In the N. W. ¼ sec. 19, 60–12 there is a ridge composed of syenite boulders three to ten feet in diameter. This ridge is 50 feet high and extends for half a mile at least running nearly east and west. It is wonderful to see these immense rounded masses of syenite (one boulder of quartzyte was seen among them) piled up on top of each other with crevices ten or fifteen feet deep between them. No rock is seen in the woods on the south side of this ridge, with the exception of a few boulders. This moraine seems to lie just south of the magnetic quartzyte.

Iron lake. This small lake is one of the few bodies of water that lie south of the summit of the Giant's range and yet nearly as elevated as the range. It is situated in secs. 13, 14, 23 and 24, 60–13. Its shore is surrounded by boulders, mostly syenite, from the ridge north of the lake. There are also, however, many angular pieces of magnetitic quartzyte. This rock contains less olivine here than a few miles further east. A few boulders of a quartz conglomerate with a green matrix were seen on the east side of the lake in the N. W. ¼ sec. 24, 60–13, No. 364.

A short distance east of the lake, in the N. W. ¼ sec. 24, 60–13 the bed rock was exposed in the hillside by a windfall. It is the usual black, magnetitic rock lying in nearly horizontal strata. Some of the rock here is reddish and jaspery; there is also a conglomeritic aspect in places. Sometimes the rock is slaty in thin, black, parallel strata that are quite straight for a rod or more. Again the iron seems to be in veins which do not conform strictly to the general planes of stratification. The following cut is from the perpendicular face of a ledge in N. W. ¼ sec. 24, 60–13.

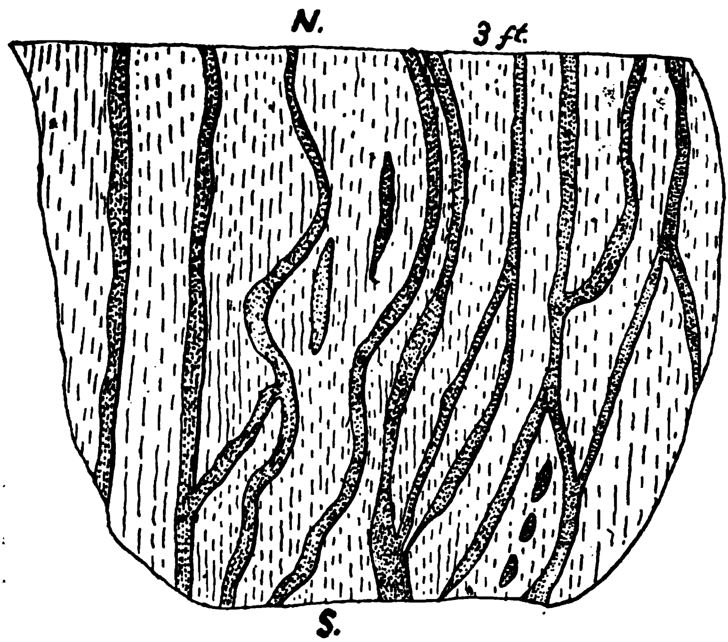

Fig. 1.—*Veins of magnetite in greenish Animike rock.*

A short distance N. W. or N. of last the ledge is exposed in a perpendicular wall 8 feet high and a couple of rods long. It is in thick black beds that have a high specific gravity and are crystalline with a dark mineral that may be hornblende, No. 365.

Near the north end of Iron lake, in S. W. ¼ sec. 13, 60-13, the magnetitic quartzyte undergoes a queer metamorphosis. It still lies in nearly horizontal beds; but it gradually becomes less highly charged with magnetite, acquires feldspathic and quartzose materials and finally is changed to a regular, reddish crystalline rock which is the syenite of the Giant's range. The lowest beds are the most perfectly crystalline. Before the transition becomes complete the Animike rock appears to be feldspathic in spots as if there were boulders of syenite in it, but lower down the beds become wholly syenitic. The quartz grains that are first seen in the greenish Animike rock have the same bluish translucent appearance as those in the syenite which lies just north. This change is illustrated by specimens numbered 366.

The quartz grains are seen before the feldspar. There are also

portions of the Animike which are conglomeritic and are the same as the peculiar conglomerate, 364. A sample which contains part of a felsitic boulder is 367. The dip needle is but slightly affected here.

North of Iron lake the land does not rise suddenly; but there is a gradual upward slope for about half a mile when the summit of the range is reached and there is an abrupt descent of 200 feet or more. Syenite containing a little biotite is seen in the bluff on the north side of the range. One sample from the N. E. ¼ sec. 14, 60–13 is 368.

There are no exposures of solid rock on the N. W. side of Iron lake. On the S. W. side in the N. E. ¼ sec. 23, 60–13 there is a ledge of black magnetic rock, 369. It presents the usual characteristic aspects of this formation; lying in nearly horizontal strata and containing more or less magnetite which gives a dark color to the rock.

Iron lake is nearly as elevated as the summit of the Giant's range. The black rock on the north side of the lake is close above the syenite; and the change which was observed to have taken place must be mainly in the nature of a fragmental transition rather than a metamorphic one, i. e., the gradual increase within the Animike of the feldspathic and quartzose materials must be due to the fact that there was more or less debris derived from the crystalline ridge on the north which was covered up by the Animike deposits and by subsequent metamorphism incorporated closely into them. That this metamorphosing process was in the nature of a slow rearrangment and reuniting of the mineral constituents rather than of a violent and more sudden disturbance seems to be indicated by the comparatively undisturbed position of the strata.

Mr. Willard went south from the lake through the S. W. ¼ sec. 23, and the W. ½ sec. 26, 60–13. He reports fragments and low outcrops of the dark iron ore rock all the way to the swamp in the N. W. ¼ sec. 35, 60–13. Sample from that locality is 370. It is tough, black, heavy rock and contains probably 45 per cent (?) of iron.

The percentage of iron in the rock appears to grow less going westward from Dunka river; toward the northern edge and westward there is also less olivine and more quartz. Fragments of red jasper are seen all along the trail. These may have been transported from north of the Giant's range, although red jasper and quartzyte have been seen in the Animike formation in this

region. Pieces of porphyritic rock that look as if they belong to the same formation near its contact with the syenite are also seen along the trail.

Some pure quartzyte containing, however, a small amount of magnetite, is found in angular fragments. A sample of reddish-gray quartzyte from N. W. ¼ sec. 32, 60–13 is 371.

The bed rock is seen to be just beneath the moss and light drift covering for two or three miles in sections 28, 32 and 31, 60–13. Ridges composed of granite and syenite boulders are seen at intervals, and evidently form part of a morainic system. The drift deposits become thicker toward the west.

Just south of the trail in S. W. ¼ of N. W. ¼ sec. 32, 60–13 is a large exposure of the semi-crystalline fragmental rock which intervenes between the regular Animike and the syenite, and grades into the latter. This rock is exposed here to a depth of 12 or 15 feet. At the top it contains considerable green, uncrystallized material, and the feldspar crystals are not so well formed as farther down where there is less of the green matter. There is an indistinct gneissic structure which seems to lie nearly horizontal; there is also a coarse schistosity which runs N. E. and S. W. At the top is a conglomeritic layer which contains pebbles of quartz and some of greenish rock, some of them two inches long, but mostly less than an inch in length, No. 372.

The rock at the bottom of this exposure is almost wholly crystalline with the usual constituents of syenite. The hornblende crystals are the last to be developed; large crystals of feldspar appear in the green matrix before it begins to show any other signs of crystallization. These feldspar crystals are orthoclase and are sometimes blood-red.

Peter Mitchell uncovered the iron ore beds in several places in the S. W. ¼ sec. 32, 60–13. Some of the rock thus exposed is quite slaty, 373. The shaft in the S. E. ¼ S. W. ¼ sec. 32, 60–13 is about 8 feet deep. It penetrates solid, black rock containing magnetite in grains and poorly defined layers or bands all through it. It is poor ore. On the surface a short distance northwest of the shaft the rock is more unevenly bedded and consists of thin veins of black ore in a gray rock. No. 374. The needle dips at all angles in a very small radius here. Glaciation is about N. N. E. Some of the rock is fine and jaspery with a reddish tinge, No. 374 A.

This is in a low ridge trending N. E. and S. W. or thereabouts. Sometimes similar ridges are seen made of boulders,

and sometimes of syenite. In the S. W. ¼ sec. 31, 60–13 is a small ridge composed of iron ore rock. It has been broken off and the land east and north is lower. The east face of the ledge is smooth and vertical and can be followed for half a mile on the north side of the trail. The grayish, quartzose rock lies in nearly horizontal beds, all of which contain magnetite. This rock always weathers shiny, smooth and black and has the appearance of solid iron. There is very little pure ore in these beds. A sample from the S. W. ¼ sec. 31, 60–13 showing the weathered surface is 375.

There is a large exposure of the Animike rock and a shaft dug down about ten feet by the side of the vertical exposed wall of rock in the N. E. ¼ sec. 11, 59–14. There is here seen a thickness of 15 feet of the usual dark-colored rock. It is, however, reddish in streaks and contains a little hematite with the magnetite. At the bottom of the shaft, particularly, the rock is soft and hematitic. At the surface of the ground the rock is harder and seems to be composed of reddish quartz in fine grains strongly resembling the "chalcedonic" quartz of Vermilion lake, 376. Hematitic rock from the base of the shaft is 376 A. There are thin bands of good ore contained in the rock here; but there is not enough to pay for working. This ledge is on the west side of a ridge which trends to the northwest. The strata have a little higher dip than usual toward the southeast. Some of the ore is seen to be further altered to limonite.

In the N. W. ¼ sec. 11, 59–14 is a small outcrop of Keewatin rock.* It lies in vertical beds striking N. 80° E. Sample is 377. In the S. E. ¼ of the same section and particularly in the S. E. "forty" there is a great deal of this rock. It rises in a ridge 15 feet above a cedar swamp. It is feldspathic or felsitic and stands in vertical strata having the usual strike for this formation. Samples are 378.

Prof. A. H. Chester, in the Eleventh Annual Report Geology of Minnesota, p. 156, speaks of hematite boulders in a layer of black sand, which he observed at the bottom of a shaft 15 feet deep in Animike, a short distance north of here. Perhaps they were on top of the Keewatin and were covered up by the Animike sediments.

The Animike beds appear to be considerably broken in this region. Several very large masses of strata were seen that were

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*This is believed to be the first observation reported of the existence of the green schists of this formation south of the Giant's range.

in horizontal position and evidently but slightly disturbed from their original position. Some of them are on the hill above the Keewatin and only about 200 feet away from exposures of it in the S. E. ¼ sec. 11, 59-14. There seems to be no reason to doubt that the black iron ore rock lies horizontally and unconformably on the upturned edges of the Keewatin. We dug a shaft by the side of a large, flat-lying mass of Animike here. It was not proven to be certainly *in situ;* but had evidently been but slightly disturbed. In this same section in various other places Animike in place is found lying above exposures of Keewatin quite near; but no actual contact was seen.

There is another shaft in the iron ore rock in the N. W. ¼ sec. 14, 59-14. It lies nearly horizontal and the rock has the usual gray, arenaceous, magnetitic appearance. It is glaciated on the surface but the direction could not be taken owing to the magnetic disturbance. One sample from here is 379.

The black slates and quartzytes in sec. 22, 59-14 do not seem to be so magnetitic, but contain veins or bands of blackish quartz or jasper. This jasper is granular and upon being pounded it crumbles and displays many white grains. The rest of the rock is grayish and is penetrated by fine needle-shaped crystals of hornblende (?) No. 380.

In the S. E. ¼ sec. 17, 59-14 there is an outcrop of the schist which is supposed to be Keewatin. It is in vertical beds which strike N. 75°—N. 80° E. It is dark gray and soft but siliceous and sericitic, 381. This is only about one mile south of Hinsdale and is remarkably close to the syenite ridge which rises 150 feet or more higher, a mile north of this exposure. The syenite appears only half a mile north of here. The dip of the schists is vertical or at a high angle to the south.

The rock which forms the highest part of the Giant's range at Hinsdale is syenite which frequently has a distinct vertical gneissic structure. This syenite is reddish near the surface, but is gray about 30 feet below. It contains porphyritic crystals of pink orthoclase, which become deep red in places. There are lenticular masses of dark, hornblendic rock inclosed in this syenite at all depths. Some of these inclusions are five or six feet in diameter. They are always elongated perpendicularly and consist generally mainly of hornblende, 383.

A few intrusions of fine gray granite and pink granulyte are seen to penetrate the syenite. Epidote colors the rock in the proximity of veins and faults or fractures. Quartz and feldspar veins of limited extent are not uncommon.

The rock is a handsome one for ornamental purposes, and columns or blocks of any required dimension quite devoid of flaws or cracks can be obtained. It has been quarried for the manufacture of paving stones. It is also being employed in the erection of the Round house of the D. and I. R. R. at Two Harbors. Twenty-five samples of this rock were obtained, 382. Glaciation is very fine on top of the ridge, N. 22° E. The summit of the range is 120 feet by aneroid above the station at Hinsdale.

North of Hinsdale there is a rapid descent in the level of the country. At one mile and a quarter from the station is a low outcrop of syenite. It is quite similar to that in the ridge. It outcrops again at 2 miles and still again at about 3 miles north of Hinsdale station. At the last place it is red and dark and the hornblende is decayed. Small geodes of quartz and calcite crystals are seen in it here. One sample is No. 385. The level here is 180 feet below the top of the ridge at Hinsdale. There is considerable drift mixed with numerous boulders of syenite at this place and all along back to the ridge.

The last syenite seen on the railroad north from Hinsdale is about five miles from the summit of the Giant's range. It is reddish and lies in low outcrops. For the next mile or two the country is low, flat and swampy. Then come knolls and ridges of Keewatin dipping about N. 75°. The dip is lower than on the south side of the ridge or at Tower. Veins of calcite are noticed in the rock.

It is noticeable that no Animike either in place or as boulders is seen north of the Giant's range. The ridge of syenite is about six miles wide from north to south where the railroad crosses it.

John Mallmann in charge of a crew of 25 men was at work in sec. 29, 59–14 sinking shafts through the drift and down to the underlying rock in search of iron ore. He finds the rock to contain both hematite and magnetite. Some of it is colored quite red by sesquioxide of iron. At depths below the surface varying from 15 to 40 feet the bed rock is encountered. It consists of thin strata of grayish rock which might be termed ferruginous quartzyte, but it is not pure quartz and iron ore. Some of it has an indistinct conglomeritic appearance, the pebbles being fine, grayish or greenish or sometimes hematitic. The beds are not as a rule more than 6 or 8 inches thick and have a low dip to the south or southeast. The syenite is said to

lie about ½ mile north of here. Much of the hematite found in these shafts shows a further alteration toward limonite.*

Red, hematitic rock having the usual dip and appearance of hematitic Animike strata is seen in a shallow railroad cut about ½ mile south of Mallmann's camp.

Mr. Willard visited Partridge river and examined some exposures of rock in the neighborhood. Gabbro was seen in a railroad cut ¾ mile north of Beaver creek, sec. 5, 58–14. It was exposed for 150 feet along the track. It was somewhat decomposed and weathered into rounded, boulder-like forms, 386. One-quarter of a mile farther south is another cut through gabbro. The same rock is seen on the south side of Beaver creek about a hundred paces from the railroad track, and in fact forms all of the knolls and is seen in all of the cuts for some distance south of Beaver creek.

On the south side of Partridge river, about in the N. E. ¼, S. W. ¼ sec. 9, 58–14 just above a small creek is a low outcrop of black or dark-gray, siliceous, thick-bedded slate which seems to dip about 20° N., 80° E. A system of vertical joints pervades this rock, the general direction of which is about east and west. About 200 feet down stream from here the river runs over the edges of these beds of slate. Following the rock for some distance down stream an old shaft is seen but no interesting features are exposed by it. It is in a ridge whose course is nearly north and south. Exposures of this same rock were noticed in several places in this vicinity; the ledges rising about 8 feet above the general level. The gabbro overflow surrounds and nearly covers this rock. The strike of the slates where the strata have been broken or lie in ridges for any distance, is N. 10° W. This rock is not exposed over a region exceeding 350 feet in diameter. It seems to be a little of the Animike formation which was not

* An analysis of this limonite, made by Mr. C. F. Sidener, gave the following:

Silica, $Si\ O_2$	3.52 per cent.
Sesquioxide of iron, $Fe_2\ O_3$	87.10 per cent.
Manganese	traces.
Lime and Magnesia	traces.
Phosphorus, P	.023 per cent.
Sulphur, S	traces.
Water, H_2O	9.70 per cent.
	100.343
Metallic iron, Fe	60.97 per cent.

covered by the gabbro overflow. It is not iron-bearing here to any appreciable extent as are the strata generally farther north. It occurs in thick, homogeneous beds in which the sedimentation is quite evident. It is silico-argillaceous and seems to be carbonaceous. Samples are numbered 387. The rock lies in lower ground than the surrounding gabbro knolls, between which and the slate a swamp intervenes.

In the N. E. ¼ of the S. E. ¼ sec. 11, 59–14 is a shaft five feet deep. No rock *in situ* appears to have been encountered in it; but many fragments of reddish-gray, quartzose rock are seen in the sides of the shaft and on the surface round about. This land is 140 feet lower than that ¼ mile north of here. Samples of reddish hematitic ore from here are 388.

About 250 paces west of the east quarter post of sec. 11, 59–14 is a shaft dug to a depth of ten feet by the face of a north and south ledge of rock. The strata here dip about 15° slightly to the south of east. Good iron ore is seen in veins or bands 2 or 3 inches thick in the face of this ledge. This wall of rock is exposed for several rods north and south of this shaft. It is noticeable that the prevalent direction of the joints in this formation is north and south.

In a part of sec. 11, 59–14 which was visited on our return to Birch lake, near the center of the section, Keewatin rock is found standing as usual in vertical strata. It is quite feldspathic. Above it, separated by a few feet only of unexposed rock covered by drift, are masses of Animike strata 15 feet long and 8 feet thick which seem to have been but slightly disturbed from their original position. A sample of the Keewatin rock is 389. There are quartz veins in it which contain talc-like scales. 389 A. Some of this vertical schist is graywackenitic and some granulitic. Some resembles the rock found at Partridge river supposed to belong to the Animike, 390.

Outcrops of felsitic, siliceous schist in vertical strata with a strike N. 80° E. are seen in N. E. ¼ sec. 15, 59–14 near the north section line; 391.

Southeast from the last about 200 paces and 40 feet higher is found a large solid outcrop of iron ore rock. It rises five or six feet and is seen for four or five rods. It is horizontally stratified or has a dip of less than 10° to the east. This is considered as certainly lying unconformably on the vertical Keewatin. No. 392 is from here.

There is another ledge of iron ore rock (Animike) in N. W. ¼

N. W. ¼ sec. 14, 59–14 near the center of the quarter section. Some good ore is found here, 393. From the way in which the Keewatin schists are found to underlie all this Animike an observer receives the impression that an iron mine or iron lands in this formation *here* are not of much value, for it is doubtful whether a shaft 40 feet deep could be made in the iron ore rock anywhere in this township without passing through it and reaching the Keewatin.

Fragments of the Keewatin rock are seen all along the trail in Twp. 60–13, indicating that it outcrops somewhere and perhaps at several localities between the trail and the syenite ridge. The number of rough pieces of Animike rock that are everywhere seen along this trail show what was the entire surface of the land south of the Giant's range and indicate that the region immediately south of the ridge was to a great extent protected from the force of glacial erosion.

A sample of quartzyte which was seen in angular fragments in 60–13 was obtained as showing fine stratification. It contains a little magnetite in bands which fade out completely in this specimen. No. 394. Deposits of magnetic sand are seen on the shore of Birch lake where the trail starts out, S. W. ¼, S. E. ¼ sec. 32, 61–12. No. 395.

BIRCH LAKE REGION.

Tonga or Dunka (sand) river. This name is bestowed by the Indians on account of the extensive banks of reddish sand and gravel which form the shores of the lake near the mouth of the stream and also compose the bed of the river for a short distance above the lake. Mingled with this red sand is more or less black magnetic sand sometimes in such quantity as to make the beach black. An instance of this is in the S. W. ¼ sec. 33, 61-12.

For a mile up this river there is a large amount of drift containing many boulders. The land rises in east and west ridges 100 feet or more above the river. Near the south side of sec. 4, 60–12 the ridges seem to be composed almost wholly of large granite and syenite boulders. It can not be ascertained certainly whether they are underlain by rock of the same nature *in situ* or not.

South of this ridge is another in S. ½, N. W. ¼ sec. 10, 60–12* which has, exposed on the surface, many angular fragments of

* This ridge is referred to by N. H. Winchell, in his fifteenth annual report, p. 341.

semi-stratified rock consisting mainly of magnetite and olivine with some quartz. This rock appears to be *in situ* at two or three places on the north side of this ridge and to dip S. 70°–80°. Syenite is found in ridges south of here, and some distance south of them is found the gabbro. The Animike, therefore, has here a range of syenite between it and the gabbro. Samples of the iron ore rock from 400 paces east of the west quarter post sec. 10, 60–12 are 356. The needle dips N. 60° to 70° here.

Other localities around Birch lake. Pursuing a trail which leads south from the lake, starting in the N. E. ¼ sec. 26, 61–12 toward some claim cabins in sec. 35, 61–12 some interesting rocks were seen. A short distance from the lake is a knoll of fine-grained crystalline rock which is generally considerably decomposed and yellowish in color. It has the composition of gabbro and is apparently the rock that first cooled on the outer edge of the gabbro overflow. It contains both biotite and hornblende sparingly, also olivine and magnetite, but is principally made up of labradorite. There are spots in it of light-colored feldspathic rock which appear to be boulders whose outline is not distinguishable from the rock mass. A sample of the fine gabbro or muscovado-like rock is 396. A sample from one of the boulder forms is 396 A. These are from the N. E. ¼ sec. 26, 61–12. This gabbro appears in small, detached knobs lying on the Animike iron ore beds. These beds are somewhat disturbed and broken and vary in dip to the southeast from 12° to 30°. Near these knolls of gabbro the iron ore rock is semi crystalline, containing porphyritic crystals of hornblende sometimes two and a half inches long. Specimens from here are 397, 397 A, and 397 B. There are large outcrops of this Animike rock here. Sometimes the stratification is not very evident, but generally it is distinct and well-marked, 398.

The beds here have the same vertical joints running north and south; and present east and west vertical faces from four to fifteen feet high such as are seen south of the Giant's range. Loose, angular fragments of Keewatin schist are seen here and probably lie near the surface in the vicinity under the Animike. Some of the Animike is almost all quartz which forms a coarse granular sandstone on decomposing. A specimen from the E. ½, N. W. ¼, sec. 35, 61–12 is 399. Glaciation here is about N. 15° E.

In the S. E. ¼, N. E. ¼ sec. 35, 61–12 are several ridges of magnetitic quartzyte having vertical faces 15 feet high on the west side. A few feet west of one of these walls of rock there is

a knoll of syenite. The latter is porphyritic with pink and white feldspar and contains both biotite and hornblende, together with a considerable proportion of quartz. It rises in the knoll as high as the top of the quartzyte ridge but slopes down and runs under it. The syenite is 400. The quartzyte is in beds which are nearly horizontal and seem to have about the same texture and composition where it lies on top of the syenite as they have ten feet higher up, 401. A claim cabin is located on the syenite ridge only a few rods from the quartzyte ledge. The syenite is cut by a few veins of fine, pink granulyte. The situation is shown in Fig. 2.

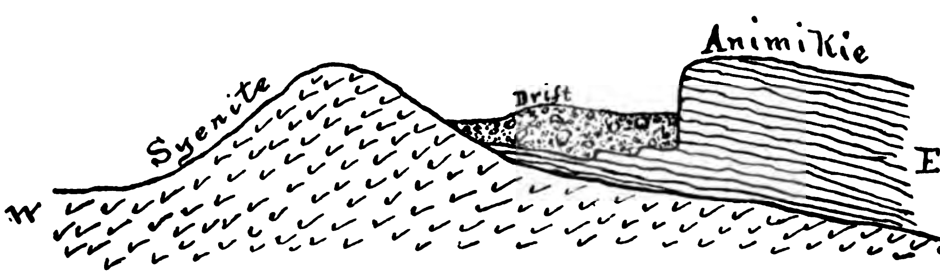

Fig. 2. Relation of syenite and Animike ridges. The little valley between the two ridges is about 12 feet deep and 35 feet across. The west face of the quartzyte is perpendicular. The land is covered with small pines.

A trench was made with some labor from the quartzyte to the syenite thus exposing the manner of contact. The Animike was found to lie on the syenite in a thin, hard, hornblendic stratum about six feet from the main mass of exposed syenite. It was buried under about five feet of till with hardpan at the bottom. Samples of the layer of Animike rock found lying on the syenite are 406.

In the first shaft that was dug down at the foot of the Animike bluff a large mass of greenish Keewatin rock was encountered that prevented further excavation at that place. This rock, which was supposed to be a drifted fragment, was coated with a crust of calcite crystals all over the top. In several places the syenite was seen to have a thin layer of the hardened Animike rock adhering to it which had not been removed by glacial scraping. From the appearance of such rock it seemed as though the abrading action of the ice was not so violent as is generally supposed.

In the N. E. ¼ of S. W. ¼ sec. 35, 61–12 the magnetitic quartz-

yte is exposed in many places. It seems to have been affected by some metamorphosing agent which has produced large crystals and masses of crystals of hornblende in it. Some of these crystals are three inches long. They frequently are rounded or lenticular as a whole mass and suggest included boulder forms, 402.

West and northwest from the last locality the ground rises and syenite is found outcropping in quite extensive ridges. This is near the west quarter post of the section.

Toward the S. W. ¼ sec. 35, 61–12 the land rises until it is 200 feet above Birch lake. On this high land many large, smooth-topped exposures are produced by recent extensive wind-falls. The strata seem to have been disturbed and slightly elevated by some force from beneath. The usual dip—less than 30° to the southeast—is, however, still maintained. This rock is coarse and more quartzose and has quartz veins penetrating it. Glaciation is finely exhibited in many places and seems to vary, as near as could be estimated, by comparison with the section lines, from N. 12° E. to N. 30° E. Syenite is reported to outcrop about one-half mile west of the S. W. corner sec. 35, 61–12. Some of the beds of this Animike rock are but slightly iron-bearing and are almost wholly composed of olivine, 404.

In the N. ½ of the S. E. ¼ sec. 24, 61–12 there are several exposures of Animike rock in shafts which have been dug in the search for iron ore, as well as on the surface. The rock is dark, heavy and magnetitic and exhibits fewer sedimentation bands than usual. But it has the general dip of this formation and is rich in olivine. There have been six or eight shafts sunk at this place; some of them are nine or ten feet deep and furnish good sections of the rock strata. Some thin strata of rich magnetite are seen in the rock; but they are always separated from each other by beds of poor ore or of quartzyte, 405. Much of this rock is hornblendic; the crystals appear right in the middle of olivinitic and finely granular strata containing more or less magnetite. These crystals of hornblende are in the strata ten feet below the surface beds, and are sometimes two inches long or more, 405 A. In places the rock has been moved on itself and has thus formed fine slickensided surfaces, 405 B.

There is a heavy covering of drift sand and boulders here. Granite in place and gabbro lying on it were seen a short distance farther east in the S. E. ¼, N. W. ¼ sec. 24, 61–12. The Animike beds seen in the vicinity were in knolls that rise above the

granite and gabbro and are estimated to be 150 feet above Birch lake. A thickness of about 25 feet of the iron-bearing strata was seen in the various shafts.

This same rock outcrops on the west side of the little bay in S. E. ¼, S. W. ¼ sec. 24, 61–12, a short distance back from the shore. At this place it is much decayed and jointed.*

Vicinity of Kawishiwi river. Going south on the range line between townships 62–10 and 62–11 on the south side of the river in S. E. ¼ sec. 13, 62–11, search was made for the iron ore reported by Mr. Lorenzo Cleaves. Nothing was found for half a mile except syenite in a ridge about 75 feet, by aneroid, above the river. Then there is a swamp and a creek, and gabbro hills are reached in S. W. ¼ sec. 19, 62–10. These hills are but a little over 100 feet above the Kawishiwi. The gabbro is seen in bare knobs and vertical bluffs 20 to 40 feet high. Some masses of gabbro 30 feet in diameter have been pushed up on top of the smoothed knolls of solid rock and left there by the ice.

In the S. E. ¼ sec. 30, 62–10 are several shafts, some more than 20 feet deep, in magnetite ore. The magnetic attraction is very strong here and the needle dips 90°. There being more than a mile and a half of gabbro north of this place and this iron ore itself being in hills of gabbro 100 feet high it would naturally be supposed that this ore is gabbroitic magnetite and therefore titaniferous.

But the ore is olivinitic and generally quite fine-grained, and the rock which contains it is not a massive crystalline rock like gabbro, but stands in beds which are nearly vertical, though the dip is not constant. These strata are olivinitic and besides being finely granular, possess a banded structure and are evidently *transported beds of Animike strata contained in the great gabbro overflow.* Whether they are between overflows of different dates or were surrounded and taken to their present position at the time of a single eruption was not evident, but the latter is more probable. The gabbro itself being also largely composed of magnetite here renders it more difficult to distinguish between the two kinds of rock. Samples from the S. E. ¼ sec. 30, 62–10, showing banded structure supposed to be due to sedimentation are 407. Specimens of the coarse gabbro magnetite are 410. The Animike is quite hornblendic here as at the locality north of Birch lake, sec. 24, 61–12. The gabbro which forms massive knolls all around this place is not so much decayed as the iron

* N. H. Winchell, Fifteenth annual report, p. 335.

quartzyte, nor does it display any banding nor any other signs of bedding as do the enclosed strata of Animike.* The general strike of the latter is east and west.

A trip was made from the Kawishiwi river in N. W. ¼ sec. 25, 63–10 southeastward into sec. 36. Gabbro ridges and knolls from 70 to 100 feet above the river are crossed. Many large fragments of greenish schist from farther north lie on the surface, also boulders of syenite and amphibolyte or dioryte. This gabbro is rather coarse and is magnetitic in spots and streaks; 412. There are belts of coarse hornblende and labradorite found in it. 412 A. Included in the gabbro are irregular masses of all sizes of fine, grayish rock that seems to be composed of rounded grains and resembles Animike. There is no evidence left of former stratification, and in places where it has been highly altered this rock has the composition of a fine gabbro. But the transition from it to the gabbro is always abrupt and the outlines of the included masses of it are plainly seen. 413. This rock is slightly ferruginous if at all; but the gabbro contains much shining, coarsely crystalline magnetite. 414.

In the S. E. ¼, S. E. ¼ sec. 25, 63–10 the gabbro contains some large masses of very coarse hornblende. There are places in the gabbro four to six feet in diameter which contain or are wholly made up of black hornblende crystals six inches long. There is a little mica in connection with it, also some coarse labradorite. 415.

Vicinity of Long Lake. The hills in the N. W. ¼ sec. 20, 63–12 are composed of diabasic rock. They rise about 100 feet above

*An analysis of the magnetite supposed to belong to the enclosed beds of Animike and therefore to be non-titaniferous, was made by Mr. C. F. Sidener. No titanium being found in it the effect of the gabbro does not seem to have been intense enough to invest the magnetite with harmful ingredients.

Silica, SiO_2	11.39 per cent
Alumina, Al_2O_3	Traces.
Magnetic oxide of iron, Fe_3O_4	85.55 per cent
Titanium, TiO_2	None.
Lime, CaO	.22 per cent
Magnesia, MgO	3.44 " "
Phosphorus, P	.02 " "
Sulphur, S	Traces.
	100.62 " "
Metallic iron, Fe	61.95 " "

the lake, and in them are seen the same coarse boulder forms* as have been noticed in this rock farther east, also at the railroad cut near the Chandler mine, on the south shore of the lake in sec. 28, and in the N. E. ¼ sec. 5, 62-12. On the north side of the first ridge north of the lake the rock is not so diabasic, but is the usual more or less fissile sericitic schist.

In the N. E. ¼ sec. 9, 63–12 the sericitic schist changes rapidly across the strike, going north, into granite, becoming first siliceous, then felsitic or feldspathic and finally micaceous. Specimens illustrating this are Nos. 416 to 416 E. The granite still preserves in places a coarse vertical schistosity. North of this granite, which continues only for a short distance, is hornblendic biotite schist crossed by veins or intrusions of syenite and granite; 417. This dark schist is in vertical strata having the usual strike of about N. 60° E. The lake which lies in sec. 4, 63–12 is about 75 feet higher than the lake just south of it.

Going overland from the lake to the N. W. corner sec. 4, 63–12 the rock is found to be hornblende-biotite schist dipping north at an angle of 75° or more. Most of it is very dark colored and heavy, 418. Nothing was seen of the belt of magnetic iron which had been reported to exist in this section.

Going south from Ely into sec. 4, 62–12 the rock is found to be mostly covered by a thick deposit of drift until the N. W. ¼ sec. 4 is reached. Here there is seen an abrupt ridge of sericitic green schist striking N. 60° E. and having a vertical dip. This ridge rises 75 feet above the swamp on the north side of it. The rock contains considerable calcite as at Ely. 419. Going west several pits are seen dug in the low ground north of the ridge. All of them penetrate a soft reddish rock strongly impregnated with iron similar in appearance to that in the mines at Ely. It seems probable that the depression north of this ridge may have been produced by reason of the softer nature of the iron ore beds which may lie in there. And it is not at all unlikely that rich beds of soft ore underlie the swamp referred to. In the N. E. ¼ sec. 5, 62–12 a large, glaciated surface of the green rock is exposed. There is here a fine exhibition of the coarse agglomeritic structure mentioned above. A diamond drill just east of this place has gone down 60 feet in the same rock.

*This is referred to by Mr. A. C. Lawson in his report on Lake of the Woods as a "concretionary (?) trap structure."

LAKE SUPERIOR TRIP.

The country south and east of Bald Eagle lake (the Indian name for this lake is *Mishiwishiwi sagaegan* or Beaver-house lake) has been burnt over and is now covered by a small growth of aspens, birch, jack pine, spruce, etc. It is rocky and hilly, the hills of gabbro rising 100 feet or more above the general level. The route to lake Superior lies up the river which enters the south side of Bald Eagle lake. This stream is smooth for a short distance and has low swampy banks. A rapid where the river falls 50 feet is then encountered and above it again the smooth, currentless stream. The solid rock is all gabbro and most of the boulders are of the same material, though there are a few boulders of Keewatin greenstone and of granite. On the first portage there are seen some large pieces of white vein quartz. The gabbro for a mile or two is almost wholly composed of labradorite. In one place was seen quite an accumulation of boulders of siliceous greenish rock like that at the west end of Knife lake.

The land in the S. W. ¼ of township 62–8 is quite uniformly level. The lake in sections 29 and 32 has low shores, mostly marshy. The rock is gabbro, many boulders of which lie around. The lake and river seem to be almost on top of the gabbro ridge, the hills around them are so low.

Lake Isabelle. The shores of the west side of this lake are composed of gabbro. They are generally about ten feet high, but sometimes rise to forty feet. The gabbro is very much decayed near the surface. It is composed principally of labradorite; but contains some biotite and a little magnetite. There are occasional small pieces of granular olivinitic rock, supposed to be Animike, enclosed in the gabbro. They are hard and sometimes have a basaltic structure. A sample of gabbro from N. W. ¼, S. E. ¼ sec. 35, 62–8 is 420. There are numerous boulders of fine siliceous greenstone from farther north seen lying around the shores of the lake. The Indians call this lake by the same name as Gabbro lake, viz.: *Kazushkonabigka-gamak*, the lake-with-the-shores-of-shelving-rock. On the east side of the point last mentioned is a beach of sand and pebbles. The latter consist of siliceous greenstones, porphyrytes, granites and gabbro, 421.

The gabbro in the bay east of this point is smoothed by glaciation and considerably decayed. It contains in one place ten feet of hard, greenish rock in a dyke or bed about a foot wide, which

seems at first to be trap, but is not massively crystalline and seems to contain some rounded grains, and therefore may be Animike rock hardened by the action of the gabbro.

In the S. W. ¼ of S. E. ¼ sec. 36, 62–8 there is a dyke 16 inches wide exposed for 30 feet. It is perfectly straight and is composed of tough green rock. The dyke walls are well-defined and it maintains the same width for the whole distance of its exposure. This rock hardly appears like trap; it is too granular and not sufficiently crystalline. Neither can it be said to resemble the Animike rock. The direction of this dyke is N. 64° E. 422.

In the S. E. ¼ sec. 36, 62–8 the gabbro stretches out in long, low reefs into the lake. Beds of sand which is the result of rotting gabbro occupy the hollows. There seem to be layers or beds in this gabbro that are like the rock found in the dyke, 422. The question arises whether this rock was igneous and flowed over on the gabbro or whether it is changed Animike enclosed in it. Glaciation is N. 24° E.

Some of the gabbro is fine grained and brown and contains more biotite than the gray. Perhaps this is what has been called "muscovado." One sample from the south shore of the lake just east of the range line in Twp. 62–7 (unsurveyed) is 423.

Swamp Lake river (*Maskigo-sibi*) enters lake Isabelle on the east side. This river is a series of lakes connected by a small stream. About two miles up this stream a change takes place in the gabbro. It is found to be composed of re sh feldspar and much hornblende with a little biotite, magnetite, pyrite and sometimes galena. Streaks of this reddish gabbro are first seen running through the gray and then it all becomes red, and large massive knolls are formed of it. Nos. 424, 424 A. and 424 B. illustrate this change.

The route to lake Superior lies through the series of small lakes connected by a stream which comes from the east and southeast. This stream is very rocky and full of rapids and comes from Kaminisabikokak lake which has been re-named lake Bellissima. This lake is about two and a half miles across from east to west and four miles long from N. W. to S. E. It is situated in the southeast part of Twp. 61–7, and perhaps extends into Twp. 61–6. Notwithstanding the rapids in the river a person receives the impression that the country is unusually level. No hills of any considerable hight are seen, and at times the stream is merely a narrow lake a mile or more in length with a low

rapid at each end and shores not over 20 feet high. The country has all been burnt over and the only trees are small poplar, birch, willow and jack pine. A great many boulders principally of gabbro are seen on all hands. There are also boulders of trap and red Cupriferous rock for two or three miles west of Bellissima lake. The solid rock is all gabbro. West of the lake it is nearly pure labradorite, but toward the east it is associated with a larger proportion of magnetite. It decays rapidly and crumbles apart forming beaches of sand which is nothing but decomposed labradorite feldspar. The Indian name for this lake is applied with reference to the large number of boulders which line the shores and stand several feet out of water at some distance from the shore all around the lake.

There are sand and gravel beaches, beaches of small cobble stones, beaches of moderate sized boulders, and beaches where the boulders average more than six feet in diameter, while some are fifteen to twenty feet. The largest boulders are of gabbro; but many of the smaller ones are greenstone or red amygdaloidal trap. There are comparatively few exposures of solid rock around this lake, but all the rock that is seen is gray gabbro.

The stream which enters the southeast corner of the lake is canoeable for only a short distance, about half a mile above Bellissima lake. A portage of a half a mile is then made to a small lake and then another portage of one and a half miles south to lake Gaokakag, or lake Harriet. The country has a heavy covering of drift sand and gravel and but little rock is exposed. Many of the pebbles and boulders are from the Cupriferous. Occasionally there is seen an outcrop of gabbro, quite coarse and containing considerable magnetite. The surface is rolling and open, having been burnt but a few years ago.

Lake Harriet is about two miles long. It is a beautiful body of water set in hills heavily covered with white pine around the south half of the lake. High water is maintained in it by a beaver dam at the outlet. The long portage necessary to make in order to reach the lake from the north cuts off an impassable part of the river. This lake is 70 feet higher than the small lake at the north end of the portage. The country between these two lakes is good farming land, but is now nearly bare, having been burnt recently.

At the outlet of lake Harriet there is a massive exposure of reddish-gray rock, which crosses the river and forms a rapid.

This rock is a phase of the gabbro. Some of it is fine and hard and very tough. It is composed of hornblende, biotite and red feldspar. A little farther south the rock is coarser and contains a small amount of gray labradorite. Then the two kinds of feldspar occur in equal proportions. From here the red feldspar fades out until the usual condition of the gray gabbro is reached. Where the fine, hard, reddish-black rock is first seen it does not look at all like gabbro. Nos. 425 to 425 C illustrate the change.

Hornblendic gabbro is seen in a low exposure not far east of the north end of the lake. No. 426.

This lake is situated in secs. 20, 29 and 28, 60–6. Very few exposures of rock are seen around it, the shore being mostly composed of the drift which supports such a fine growth of pine. Hills of drift 60 feet high surround the lower end of the lake. A few boulders are seen on the lake shores, but they are mostly sandy. There is an immense accumulation of boulders just north of the lake — large bare ridges of all sorts of boulders, trap, gabbro, Cupriferous, Keewatin, porphyry, granite and Animike slate. These ridges are evidently morainic deposits.

A short portage of 285 paces leads southeast from lake Harriet to Pine lake just east of it. Some trap and a peculiar rock of various colors and texture were seen on this lake. The notes here were taken by Mr. Grant.

A half mile portage leads across the divide from Pine lake to a small, nameless lake 30 feet lower. No rock was seen around this lake.

A long portage, over two miles, leads south to *Kapokegamak or Crooked lake*, in Twp. 59–6. The country is all covered with a fine growth of green timber. The drift is rich and evenly distributed and the land is good for farming.

In sec. 15, 59–6 some fine-grained, olivinitic gabbro was found. It is cut by extensive dykes of green trap.

A sample of gabbro which was found in place on the west side of Crooked lake is 428. Steep hills of trap occur just west of the northern narrows, sec. 15, 59–6. This trap is porphyritic with green feldspar(?). It outcrops in several spots around the lake south of here. 429. Glaciation is N. 6° E.

From Crooked lake a short portage leads south to a small nameless lake on which no rock was seen. From here a portage of one-half mile leads to Nine Mile lake, so-called because it is nine miles by trail to lake Superior and no more canoeing. On

the north and west sides of this lake are exposures of rather fine-grained, olivinitic gabbro. 430.

Following the nine mile portage trail south a distance of one mile a small pond less than one-fourth mile long is encountered. This is 75 feet lower than Nine Mile lake. In the next half mile the trail rises 220 feet and reaches a pond 205 feet above the last small lake. Lake Superior can be seen from the hills surrounding this pond, which rise 75 feet above it. The land on the south shore of the great lake can also be seen with the naked eye. This pond is supposed to be in sec. 35. 58-6.

The creek which flows from the pond runs in a deep gorge. The east wall of this gorge is Cupriferous and the west wall is fine-grained olivinitic gabbro or trap. This is the first true Cupriferous seen on this route. It rises in high, precipitous hills consisting of a reddish felsitic rock very much jointed and containing light and dark spots and streaks. Several shafts have been dug at the foot of the gabbro ridge on the west side of the gorge mentioned above. Fragments of the reddish Cupriferous rock were thrown out from all of these pits; and in fact that is apparently the only rock found in digging them. In one of these shafts the red rock seems to be in place. This is just below the lofty bluff of gabbro which therefore seems to lie upon the Cupriferous here. Still they may be side by side and neither one be above the other. The gabbro contains more olivine and less magnetite than that seen six miles north of this place. The general boundary line between the gabbro and Cupriferous runs through the south tiers of sections in the east half of township 58-6. Samples of the gabbro are 431. The Cupriferous is 432.

Between this high ridge and the range of hills just north of the lake there is a low, broad valley heavily timbered. The trail does not cross the highest part of the ridge along the lake shore, but follows the valley of a small stream which seems to have cut a gorge through the ridge, but probably followed a natural depression. No rock was seen exposed south of the gabbro ridge. The trail descends 1125 feet between the small pond mentioned last and lake Superior. There are hills around this pond 100 feet high, and the gabbro ridge is therefore 1225 feet by aneroid above lake Superior, or 1827 feet above sea level. This trail comes out at Pork bay. The hills at the west side of this bay rise 330 to 460 feet above the lake.

GUNFLINT LAKE.

A small stream from the north enters the east end of the lake just north of the boundary river. A few rods west of the mouth of this creek gabbro is seen lying in Animike slates. About one-eighth of a mile up the creek rock in place is noticed. This is a ridge of vertically bedded rock supposed to be Keewatin. Strike is N. 80° E. Dip is not constant. Some of it is fine-grained and flinty and resembles the Knife lake rock. 433. Farther up on the east side of the creek the same rock is coarser and not so siliceous, but contains chlorite or sericite. No. 434.

It was because of reports of red jasper being found here that a visit was made to this creek. This jasper was found to be in beds of Animike lying horizontally on the opposite side of the bed of the creek from the Keewatin. The bed of this stream lies in the line of contact between these two formations. The Animike is flinty and becomes more reddish farther up the creek, 435.

About one-quarter of a mile up the stream the creek spreads out into a marshy lake. A north and south Canadian survey line between 297 T and 298 T crosses the creek at the head of the rapid water. At this place, on the east side of the stream, are thick beds of horizontal Animike. It has here the nature of a somewhat decomposed, fine, dark conglomerate. The pebbles in it are iron rusted; they are sometimes an inch long, but generally less than half an inch. They are flattened horizontally, 436. On a knoll above this conglomerate, a short distance east of it is found another outcrop of schistose Keewatin. It is greenish and somewhat sericitic, 437.

In the bed of this same creek there is found the contact between Keewatin and Animike. The two rocks are very similar in appearance and texture at the point of contact, and it is only by following up what is plainly Keewatin on one side and what is known to be Animike on the other until they come together that the junction could be determined. Even then the actual line of contact could not be seen, being in the bed of the creek of running water; but a person can stand with one foot on rock that is plainly horizontally stratified and is magnetitic, and the other foot on a slightly different rock that is lighter colored, contains no magnetite and has vertical bands of sedimentation. The space between is occupied by rock that may belong to one formation or to the other and is somewhat

broken up. The best place to observe this contact is at the water's edge on the east side of the brook. The Keewatin strikes N. 80° E. and has a high dip to the north or is vertical; a little farther down the creek, however, it dips S. 75°. A ridge of the Keewatin on the east side of the stream rises above the Animike which lies unconformably in almost flat beds upon and against it. The Animike is 438. Specimens of the Keewatin are 439.

Going south from Gunflint lake to Loon lake a ridge of gabbro 300 feet high is crossed. Loon lake is 195 feet above Gunflint by aneroid. Mayhew lake is 110 feet above Loon lake. It is surrounded on the west side by low gabbro hills. This gabbro contains considerable magnetite. Several claim cabins are located on this gabbro ore. The gabbro in Tucker lake just west of Mayhew lake is also magnetitic. It is quite coarse and decayed and presents a gneissic or foliated appearance. A sample from N. E. ¼, N. W. ¼ sec. 2, 64-3 is 440. In the S. W. ¼, N. W. ¼ same section there is some fine dioritic looking gabbro which also contains magnetite. 441. This lake being 305 feet above Gunflint it is not likely that there is any Animike exposed on its shores; and indeed none was seen.

In the S. E. ¼, N. W. ¼ sec. 2, 64-3 the gabbro contains parallel bands of magnetite which dip S. 40° and give the rock a decidedly stratified aspect. Some of the beds or bands of magnetite are four or five inches thick, others only a fraction of an inch. No. 442.

The gabbro on the south side of Tucker lake presents a basaltic structure. It is very coarse and the planes of intersection are nearly at right angles with each other. One set dips S. 20° W. 45°; the other set is vertical. The gabbro here is unusually biotitic. It also contains white feldspar equal in amount to the labradorite in places. No considerable amount of magnetite was seen around the lake. It was all mixed in with the gabbro.

The point that runs through sec. 35, 65-3, on Loon lake, is highest in the N. W. ¼ sec. 35. It is made up of hills of Animike capped by trap or fine gabbro. There is here a thickness of about 150 feet of black Animike slate dipping S. 30° or more, and 30 feet or more of trap rock on top. The slate and trap are represented by 443 and 444 respectively. There is a gradual transition between these two rocks, the slates having been somewhat metamorphosed. Large pieces of coarse porphyry are seen on top of this hill. One large mass had trap rock stuck fast to

one side of it. This rock was not seen in place here, but evidently belongs in the vicinity. Nos. 445 and 445 A. are the porphyry and trap. The Animike here appears remarkably thick and the gabbro on top of less depth than supposed.

In the N. W. ¼, N. W. ¼ sec. 23, 65–4 is a pit 12 feet deep which goes down through highly magnetitic beds of Animike for nine feet and then into the granite. This is nearly as high as the top of the Giant's range. The Animike is fine-grained and contains less olivine than that south of Birch lake, but has very much the same general appearance and lies like it, in strata dipping S. 15° to 30°. The best ore here is quite pure. About four feet thickness of this good ore is seen at the top of the shaft. 446. This ore possesses very strong magnetic properties. The beds of Animike which lie upon or closely above the syenite and granite seem to be very generally ferruginous and sometimes excellent ore.

The rock of the Giant's range here is very similar in texture to that south and west of Birch lake,—only it seems to contain mica here instead of hornblende. The gneissic structure, however, the color and the abundance of large bluish grains of quartz are suggestive features and remind one instantly of the Giant's range at Birch lake and at Hinsdale.

Gunflint lake to Ogishke Muncie. In the N. E. ¼ sec. 25, 65–4, just at the upper end of the first portage on the river above Gunflint lake is a bluff of Animike slates on the south side of the stream, 75 feet high. The northern face of the bluff is perpendicular, exposing finely the edges of the nearly horizontal strata of black slate. This bluff of slate is seen to lie upon trap rock into which it grades by the metamorphism of its lower beds. This trap or greenstone extends in a bare exposure for 20 rods or more north of the river. It is seen to be at least ten feet thick and has a surface dip the same as the slate beds. In some places it is porphyritic with white feldspar in spots or streaks: it then looks like the porphyry, 445, found south of Loon lake. There is a great exposure of this massive rock here, and it is plainly seen to run under the slate bluff. Some of the Animike is a breccia containing angular pieces of some sedimentary rock and of a crystalline rock as large as six inches in diameter.

The greenstone which is probably part of the Keewatin, is cut by a fine trap dyke 8 to 15 inches wide, exposed for 150 feet running N. 10° E. It contains pieces of the Animike or some other sedimentary rock. Two or three smaller dykes run at

right angles to this one. Nos. 447 to 447 H are from here, also No. 448, which represents the brecciated Animike.

On the trail which runs west through sections 26, 27 and 28, 65–4, no rock other than Animike is seen. The country is elevated, 400 feet at least above Gunflint lake, and yet the nearly horizontal beds of slate are found all the way up to the top. Some of it is quite magnetic, but most of it is dark carbonaceous slate. Boulders of conglomerate apparently belonging to this formation but not seen in place are No. 449. Pebbles of quartzose and feldspathic rocks an inch and a half long are found in this conglomerate.

A diamond drill has been operated on the north side of the creek in N. W. ¼ of sec. 28, 65–4. There has also been made a cross cut here up on to the hill. The beds of Animike slate and olivinitic magnetite have here a much higher dip than usual, — S. 60° — S. 75°. There is considerable good magnetite here, but the beds are not thick enough to pay for working, 450. The tilted condition of the Animike seems to be accounted for by the rock which lies under it and which rises about 100 feet above it in the ridge north. This rock is a kind of greenstone (Keewatin), in some places looking a little like fine decomposing gabbro, containing considerable biotite at this locality. It contains labradorite and olivine and very little magnetite. The Animike is plainly seen to lie upon this rock which has slightly metamorphosed the nearest or bottom bed of quartzyte and iron ore. The lower beds of the iron bearing formation here are often exceedingly pyritous. Nos. 451 and 452 are from here. The latter number is applied to drill cores from here. These show the gradations and changes of the Animike beds as they become crystalline toward the bottom and pass through metamorphosed strata into the greenstone. The manner in which the drill penetrated the beds of Animike is shown by the following diagram.

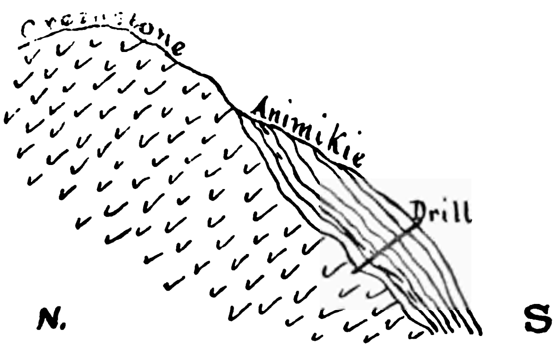

Fig. 8. Animike beds on greenstone. West of Gunflint lake. East of Chub lake.

This greenstone-gabbro ridge runs west of here for several miles, and the Animike is found to lie on it in several other localities much the same as it does here.

Another drilling was made about ⅛ mile south of the camp in sec. 28, 65–4. Samples from here are 453. These drill cores show the streaks and bands of hornblende crystals which are found in the lower beds of the Animike quartzyte; also the pyritiferous strata. Some of them contain biotite also and are partially metamorphosed into the underlying greenstone. This drilling according to Mr. John M. Millar of Grand Marais, one of the owners of the land, went through the ore in which it started, and about 12 feet into the "north quartzyte;" by which he must mean the underlying greenstone.

The same parties who did the work mentioned above also drilled in the N. E. ¼ sec. 29, 65–4 a short distance west of the first drillings. According to Mr. Millar the record for this working, which is near Chub lake,* is as follows: Quartzyte 36 feet, clean ore 15 feet, mixed ore 17 feet, clean ore 10 feet, greenstone 12 feet. Mr. Millar calls the last "the north quartzyte," but he evidently must refer to the greenstone on which the ore and quartzyte beds lie.

From this record it seems that there is a large quantity of magnetite at this place which will probably prove to be valuable. The parties who own this property are waiting only for the advent of a railroad to commence extensive mining operations. This is the first deposit in the Animike in Minnesota known to

* Mr. Millar states that the name "Akeley" was applied to this lake several years before it was called "Chub lake." No map, however, has been seen to have that name and as it has already been referred to in published reports as Chub lake, the name is retained.

be of sufficient extent. and richness to repay investment and development.

The usual route to Ogishke Muncie was not followed here, but the more circuitous one through the lakes southwest of Chub lake was taken. I can not refrain from stating here by way of parenthesis that the township plat of 65–4 is the most unreliable of any it has ever been my misfortune to be misled by. The lakes in the southwest part of the township are delineated by guess-work and very poor at that.

In the N. W. ¼ sec. 35, 65–5 is a knoll of Animike quartzyte. It has an elevation of about 50 feet on the south side of the stream. It dips south about 75° and strikes east and west. It contains thin beds of good magnetite, 454. Across the valley which lies on the south side of it, is found gabbro.

About a quarter of a mile west of the last is a portage of 100 paces around a rapid in the small stream. It is here seen that the knoll spoken of above is a part of a ridge of Animike that is found all along the south side of this marshy stream. On the south side of this portage trail, N. W. ¼ sec. 35, 65–5, is a precipitous bluff about 40 feet high, facing north. The lower half or perhaps one-third of this bluff consists of greenstone similar to that north of Chub lake, but containing less biotite. The upper half or two-thirds is Animike quartzyte and iron ore tilted up so as to dip S. 70° or more and striking about east and west. There is an abrupt line of contact here shown to exist between the quartzyte and the Keewatin (?) greenstone and the impression made upon an observer of the situation is that the greenstone is the cause of high dip of the quartzyte and iron ore beds.

This is a very fine contact. The stratified quartzyte is seen for several feet lying directly upon the massive greenstone. At this place then the Animike is but very slightly modified by the igneous rock beneath it, and on that account it seems as though the strata must have been deposited in a horizontal position on the greenstone and that both were folded and tilted at a later period. But at other places east of here a few miles the Animike is greatly metamorphosed so that the line of contact is not discernible, and the greenstone might be supposed to be all modified Animike. The greenstone near the contact is a little finer-grained and less massive than it is two feet below; but no other change is apparent. Specimens of the Animike from the contact are 455. The contact was seen again 150 paces west of

this place; but it is not so plainly visible. Samples of the Animike from the western contact are 455 A. Specimens of the greenstone from the eastern place are Nos. 456 to 456 C, taken in order receding from the line of contact. Greenstone from the western contact is No. 456 D.

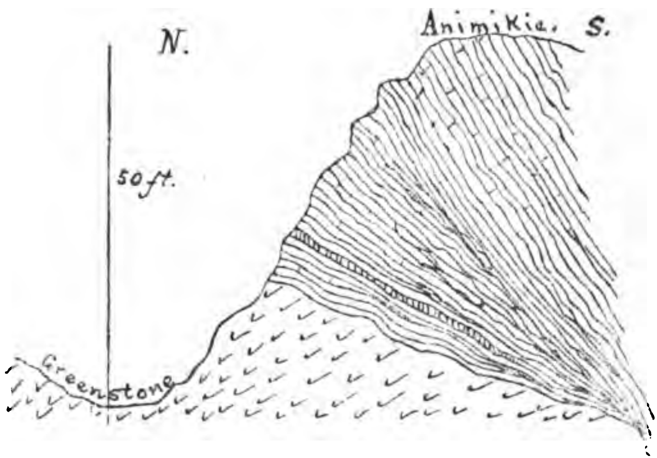

Fig. 4. Animike lying on greenstone, Township 65–5.

At the upper end of the portage are some large masses of greenstone, not in place, which are conglomeritic. Rounded pebbles and boulders of light and dark colored rock—some of them six inches in diameter—occur in it. This rock seemed to be very much like the conglomerate of Ogishke Muncie lake, 457.

On the north side of the creek from the bluff where the contact is seen there is a higher ridge than on the south side. The rock composing it does not appear to be so tough and basic as most of the rock which is subjacent to the Animike quartzyte in this region, 458. It is a fine, greenish-brown, crystalline rock containing feldspar, mica, olivine (?) and a little magnetite.

Iron ore is marked on the plat as existing in large quantities on the line between sections 12 and 13, 64–6. This locality was visited and the rock was found to be magnetitic gabbro. No good magnetite was seen. Some of the gabbro from this place is very coarse and contains coarse hornblende, 458 A.

Gabbro is the only rock found along the shore of Gabemichigama lake for some distance from the N. E. corner sec. 6, 64–5,

459. It is quite fine grained and somewhat decayed. On the south side of the island in N. W. ¼ sec. 6, 64–5, however, was found a bluff of rock rising 20 feet out of the lake, which may be modified Animike. It has gabbro on top and to the north of it. It is apparently not connected with the trap dyke which crosses the point southwest of the island on the main shore.

Iron ore being reported in the S. E. ¼ sec. 1, 64–6, this place was visited. No extensive deposits of high grade or even medium grade ore were found. The rock is gabbro which is ferruginous in spots, 461. A rock was found here, lying under the gabbro, which may be Pewabic quartzyte. It is gray and fine-granular and when decomposed resembles a sandstone. So little of it crops out of the hill here, and it is so covered by debris from above that but little could be learned concerning its relation to the gabbro, 462.

OTTER TRACK LAKE.

Red jasper and vertical magnetitic schists having been reported from this lake a visit was made to it. The lake is surrounded by high hills of siliceo-felsitic rock standing in vertical beds which strike on the average N. 65° to N. 70° E. on the south side of the lake. The strike, however, is not constant in all parts of the region bordering on the lake. In some places near the west end of the lake the evidences of aqueous deposition are unmistakable and exist in the shape of parti-colored bands running through the flinty rock. These bands do not always coincide with the schistosity which is a more general structure and subject to fewer deviations from the usual direction.

In the N. W. ¼ sec. 33, 66–6 the hills are very high, being 290 feet above the lake by aneroid. Near the lake the rock is feldspathic and graywackenitic. Farther south it becomes almost aphanitic and is flinty. One sample which shows a conglomeritic aspect of this rock is 463. A sample which is very much like the magma of the Ogishke conglomerate is 463 A. Other specimens showing the graduation into flint are Nos. 464, 464 A and 464 B.

In the bottom of the valley in N. W. ¼, N. W. ¼ sec. 33, 66–6 some of the rock is magnetitic. It stands like the rest of the rock and the ferruginous strata are very limited in extent. 465. Up on the hill east of the last are seen a couple of short twisted jaspilyte beds inclosed in the rock. They are not over a foot or

eighteen inches wide and but a few feet long. They stand vertical. The iron ore in them is magnetite. No. 466. The contact between the jaspilyte and Keewatin is abrupt. 466 A.

On the north side of Otter Track lake in what would be the N. W. ¼ sec. 27, 66–6 if the U. S. survey lines were extended across into Canada, is a perpendicular bluff of rock 120 feet high and rising still much higher a short distance back from the lake. This bluff consists of sericitic or chloritic schists in vertical beds —as far as any bedding was observed—and striking N. 75° E. At the top this rock is seen to be a coarse green agglomerate like that in the Keewatin at Long lake, made up of coarse boulders of the same material as the formation in general. It is also calciferous, and the boulders are amygdaloidal, particularly around their periphery. In fact the rock is macroscopically identically the same in every respect as that around Ely. Samples of the boulders which contain amygdules are 467. Specimens from boulders which were not amygdaloidal are 467 A. The rock between and around the boulders is calciferous and sometimes quartzose, and is very frequently a breccia, 468. This rock appears very much like the regular Keewatin schists which grade into it in this region and which grade in the other direction into the fine vertically bedded siliceous rock of Knife lake, and the same rock on the north side of this lake both of which show indisputable sedimentary banding. It is impossible to separate or distinguish a line of separation between these rocks. They grade conformably into each other.

Just east of the perpendicular bluff mentioned above, the bluffs are lower. The next one east is a cliff of magnetitic jaspilyte. The beds of ore and jasper are very much crumpled and distorted; but in spite of the folding and doubling the strata are always nearly vertical. The jasper is colored various shades of red to nearly or quite black, and the iron ore does not amount to much. There is, however, a large body of these iron schists inclosed in the green schists here, the jaspilyte continuing for 100 paces along the shore and 40 paces back from the brow of the cliff. The green schist runs into and around parts of the jaspilyte in long elbows and tongues. The contact between the two was seen in several places. It was always abrupt and vertical and the change was not gradual but immediate from one to the other. The contact lines are in all directions of the compass. The jasper soon becomes narrower and stops suddenly at both ends in the line of strike. It is a little peculiar that such a

crumpled mass of jasper and magnetite should occur in the green schists here and have no continuation in the line of strike nor any connection with the Keewatin. Samples of the jaspilyte are 469. The magnetite is 469 A. Specimens of schist and jaspilyte from a contact are Nos. 470 and 470 A. The strata in the jasper and iron cliff are generally less than half an inch thick but sometimes a stratum of jasper two inches wide is seen. Glaciated surfaces are observed on the side walls of these bluffs both at top and bottom.

The following figure shows how the jaspilyte beds are crumpled.

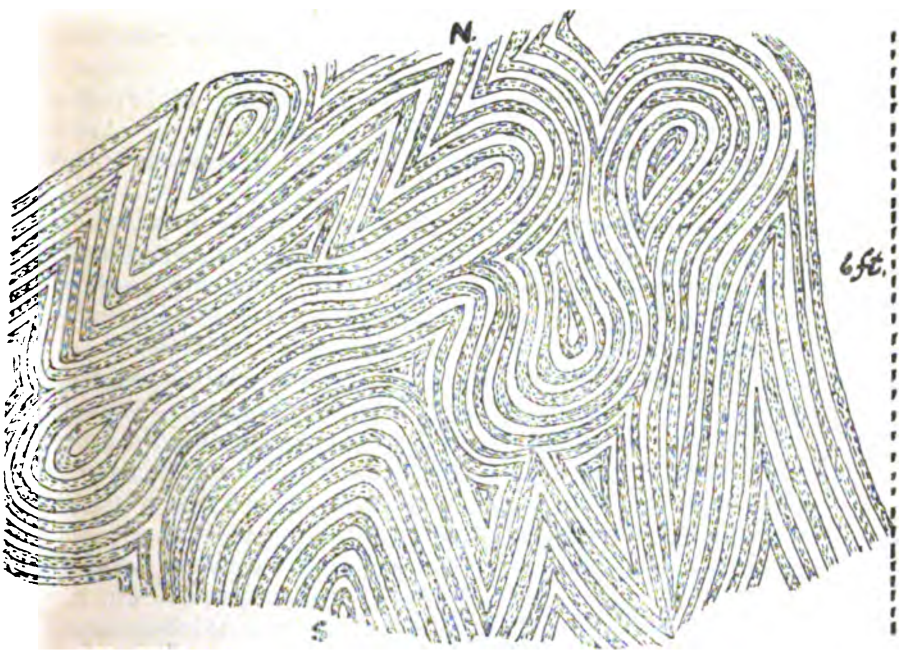

Fig. 5. Distorted beds of jaspilyte; north shore Otter Track lake.

There is a trail running north from Otter Track lake about one mile and a half from the western end. The country is surveyed and good lines are cut. The hills crossed by the trail are very high, some of them being the most elevated land in the entire region, commanding a view of the country for miles around. They are all heavily timbered and have some good white and Norway pine.

The rock is the same for at least a mile and a half north of the lake. That is, it all belongs to the same formation, supposed to be the Keewatin. It stands in vertical beds which strike N. 50° to N. 75° E. Some of it is quite finely schistose and chloritic and some becomes hard and feldspathic and semi-crystalline. A tough, green sample of the latter kind of rock is 471. It is from the corner marked "R 333" and "R 337," about half a mile north of the lake.

One high ridge consists of this green rock in a porphyritic state. The feldspar crystals are large but are not pure nor angular in shape. In fact they appear more like rounded lumps of white felsyte, but are evidently crystalline. Samples of this rock from the north side of a lake about half a mile long which lies near Otter Track lake on the north, are 472.

Coarse agglomeritic greenstone similar to that at Ely was also seen here. It always presents the fine amygdaloidal cavities and small calcite amygdules around the peripheries of the boulder forms inclosed in it.

In many places north of this lake there may be seen beds of red and black jasper and magnetite enclosed in the green rock. These deposits vary in extent and in the richness and purity of the ore which they contain. Sometimes the rock itself seems to fade into jasper and to become ferruginous and banded. At other times the rock is quite massive in appearance and has an abrupt contact with the enclosed masses of jaspilyte. The fact that some of the jaspilyte beds seem to graduate into the green rock seems to afford some support to the theory that some beds of the Keewatin formation are ferruginous, and that owing to their different composition they were not rendered hard, massive and semi-crystalline nor soft and schistose by the heat and pressure attendant upon the folding of the earth's crust, but present the evidence of having been subjected to these same forces and influences in the crumpled condition of their strata. It is very seldom that the beds of jaspilyte are straight for any considerable distance. They are almost always folded and bent as in the foregoing diagram.

Samples of the rock which seem to be grading into red and black jasper are Nos. 473 and 473 A. A sample in which the magnetite appears in the green rock and not in jasper is 473 B. The jaspilyte is 474. An average sample of the non-schistose variety of this rock is 475.

This green rock is all very much jointed and decayed far into

the seams and it is difficult to obtain fresh samples. No extensive iron ore deposits were seen. The beds of jasper and magnetite all seem to be quite limited in extent both as to length and thickness, and what there is, is at least half jasper and the other half but poor iron ore.

LAKE VIRA.

This lake is reached by a portage of 900 paces from the southwest end of Knife lake. It lies in sections 1, 2 and 3, 64–8 and is surrounded by vertical schists and argillytes. A sample of argillyte from the N. W. ¼ of S. E. ¼ sec. 2, 64–8 is a fair illustration of most of the rock surrounding this lake, 476. The strike is N. 80° E.: dip at a high angle to the north: glaciation N. 40° E. This lake does not differ much from Knife lake in hight: but it is 40 feet by aneroid above Ensign lake into which it flows by a good-sized stream.

There are high precipitous bluffs of schist and graywacke at the west end of the lake. We cut a portage of 1150 paces from lake Vira to Ensign lake. The country between Knife lake and Vira lake is burnt over, but that from Vira lake to Ensign lake is covered with green timber.

In the N. E. ¼ sec. 10, 64–8 on Ensign lake the rock is a soft, fissile argillitic schist showing no bands of sedimentation but having a wavy schistose structure trending N. 80° E. The dip is about vertical or at a high angle to the north. Glaciation is N. 24° E.

DISAPPOINTMENT LAKE.

This lake is reached by a portage of 1150 paces from Snowbank lake. There are two other ways to reach it by good portage trails. The physical aspect of the country around this lake is quite different from that around Snowbank lake. It is in a burnt region where the bare and dead tree trunks are still standing. This lake is 75 feet by aneroid above Snowbank.

About 450 paces from Snowbank lake a ridge of mica schist is crossed by the trail. The mica is in small glistening scales. The strike of this schist is N. 45° E. A sample from S. W. ¼, S. W. ¼ sec. 32, 64–8 is 477.

This mica schist is cut and penetrated by intrusions or veins of fine-grained, red granite. This appears in the next ridge

east of last, 478. Large masses of conglomeritic mica schist appear here on the surface but do not seem to be in place. This rock however is found *in situ* at the east end of the portage in S. E. ¼ sec. 32, 64–8. The schist is hornblendic and appears to be hardened. It is full of boulders of various kinds of crystalline rocks in masses of all sizes up to a foot in diameter. There is a great deal of this rock here. No. 480. A sample of mica schist from here which is not from conglomeritic beds and is more schistose than that which is, is 479. The conglomeritic mica schist is also penetrated by the red granite intrusions. 480 A. These are of all thicknesses up to 20 feet and run in all directions.

There is a dyke of trap rock on the north side of the portage at this lake. It is about 10 feet wide, and runs N. 30° W., 481. The strike of the schists here is not that of the formations generally in this region. It varies from N. E. and S. W. to N. and S. In the N. W. ¼ sec. 5, 63–8, the strike is N. 16° E.

The schist is decidedly conglomeritic in the N. E. ¼ sec. 5, 63–8. Most of the boulders are lenticular, but many of them are nearly round. The general strike, where there is any strike apparent, is N. 30° E. One sample of finely conglomeritic mica schist is 489.

In the S. ½ N. W. ¼ sec. 4, 63–8 the mica schist seems to undergo a decided change, going east along the lake shore. It becomes less schistose, contains less mica and occurs in hills and knolls of uneven hight which do not display any strike or evidence of sedimentation or schistosity. In the S. E. ¼, N. E. ¼ sec. 4, 63–8 the rock does not seem to contain any mica, but is a fine-grained, grayish-brown rock like what has been termed in some former reports of this survey "muscovado." It lies in round-topped knolls which have the shape and appearance, at a little distance, of gabbro hills. Some of it is peculiarly mottled.

Going south from Disappointment lake into the N. E. ¼ of S. W. ¼ sec. 4, 63–8 a ridge of magnetite and quartzyte is crossed. It is about ten rods wide: the strata stand nearly vertical and strike, as nearly as could be estimated, for the needle is reversed, N. 70° E. This rock is supposed to be Animike. It is olivinitic and fine-grained and the iron ore is brilliant and granular and very magnetic like the other ore from the same horizon. The only reason for doubting that it is Animike is that it stands on edge and has the "muscovado" or altered mica schist on the north of it.

Mr. H. W. Cheadle owns a claim here. He has done some strip-

ping which gives a good section of the rocks up the slope of the hill. Fine-grained gabbro is seen lying on the up-turned edges of the iron ore beds. This forms a small ridge. The next ridge to the south is composed of coarse gabbro containing a large per cent of titaniferous (?) magnetite. South of here are high ridges of this same gabbro. Nos. 490, 490 A, and 490 B show the transition from mica schist to muscovado; 491 is the Animike iron ore and quartzyte. This rock is much decayed and broken. It has suffered the effects of frost and forest fires as well as of upturning, gabbro overflow and glaciation. Fine-grained gabbro from on top of the ore beds is 492. Coarse gabbro is 493. There is quite a deposit of good magnetite here which may prove to be valuable.

The muscovado schist or rather the mica schist has somewhat the aspect of an altered igneous rock. It is not regularly schistose nor very micaceous but is full of holes and furrows, etc. The muscovado again grades into mica schist which is so feldspathic as to be almost gneiss, east of here. It is also generally conglomeritic; in some places almost entirely composed of small pebbles and boulders, in others not any being seen. Specimens of this rock from the N. E. ¼ sec. 4, 63–8, are numbered 494.

The mica schist in the S. W. ¼ sec. 34, 64–8 approaches gneiss in texture and composition. It is hardly at all schistose and in places is almost massive but has the cleavage and color of mica schist. It contains fine hornblende crystals. Some of it is firm and brittle and may be called fine syenite, 495.

In the S. W. ¼ sec. 34, 64–8 the mica schist becomes much more regular and loses its conglomeritic aspect. It is hard and fine-grained. No definite and permanent strike or dip is discernible.

Near the west quarter post of sec. 34, 64-8 the mica schist has a kind of structure which runs N. 10° W. It also becomes conglomeritic, containing flattened boulders of granite and other varieties of crystalline rock eight inches long. The longer axes of these boulders point N. 10° W. This is regular mica schist conglomerate not like the many boulders and fragments of diabasic and porphyritic agglomerate which abound in this place.

There is a great exposure of conglomeritic mica schist in the N. E. ¼ sec. 33, 64–8. It all has a general strike N. 10° W., and seems to be regular mica schist, 496.

In the N. W. ¼ sec. 34 and the S. W. ¼ sec. 27, 64–8 there is a most wonderful exhibition of conglomerate and diabase. Going

east from the point in the N. E. ¼ sec. 33 the conglomeritic mica schist becomes coarser and more full of boulders. These consist of various kinds of light-colored crystalline and dark hornblendic rocks; and are many of them a foot long. The mica schist gradually becomes harder and less siliceous until it is diabasic. East of the lake there are high ridges rising 75 to 150 feet above the water. These become more and more diabasic until they culminate in a high ridge of nearly massive diabase about a quarter of a mile from the lake. There is a coarse schistosity seen in this ridge in places. The strike of the rocks as shown by the schistosity, the direction of the longer axes of the boulders and the foliation of the mica schist are all *about northwest.* These ridges offer one of the finest exposures of conglomerate and agglomerate seen in this entire region. The rock in places is just as full of boulders as it can be. These become smaller and more compressed toward the east, and disappear altogether in the vicinity of the diabase ridge. Some of the diabasic schist is porphyritic. Samples of the conglomerate are 497. Diabasic schist is 498. Diabase is 499. Gneissic schist from the edge of the lake showing foliation which was northwest is 500. Biotite schist from a well-defined dyke about a foot wide which cuts the diabasic agglomerate, running about east and west, is 501.

It is quite remarkable that there is here a gradual transition from mica schist to diabase. There is no place where there is an abrupt change. The mica schist is conglomeritic and the diabase is agglomeritic. They are both schistose and have the same trend and seem to be vertical, as far as bedding is indicated by foliation and schistosity. It is a very thick conglomerate too: fully two miles across the strike. No attempt will be made to account for this transition here nor to prove whether there are two conglomerates here or not.

In the N. E. ¼, S. W. ¼ sec. 27, 64–8 the rock is very fine and even-grained, and so siliceous as to be flinty, 502. Glaciation is N. 34° E. No regular bedding or schistosity is seen here.

In the north end of the bay in the S. W. ¼, N. W. ¼ sec. 27, 64–8 the siliceous rock becomes porphyritic with small imperfect white and yellow feldspar crystals. It is indistinctly conglomeritic in places and is coarsely schistose, 503. Large masses of hydro-mica schist are seen here and indicate beds of this rock in the vicinity.

West of here the rock becomes a porphyritic conglomerate and in places over quite a wide extent is micaceous porphyritic

conglomerate. Many of the included boulders are more porphyritic than the magma. The strike is N. 10° W. All of this rock is more or less hornblendic. Around the lake shores the rock is peculiarly pitted and full of holes where some of the softer boulders have been washed out. No pieces of red jasper were noticed in this conglomerate, such as are seen in the Ogishke Muncie conglomerate. Wherever the rock is decidedly micaceous it is intersected and penetrated by *red* granite or syenite intrusions. This is especially the case on the large island in the S. E. ¼ sec. 32, 64–8.

ROUND LAKE.

This body of water lies west and southwest from Disappointment lake, the waters from which flow through Round lake before reaching Snowbank lake. It is 30 feet lower than Disappointment lake, and is reached from it by a portage of 540 paces. Mica schist is seen on the trail. It is more feldspathic and compact or gneissic than that farther northeast. In the N. E. ¼ sec. 6, 63–8 the mica schist changes to gneiss or syenite gneiss. There is but a small quantity of this rock here, however, most of it being a mixture of mica and hornblende gneiss and mica schist. The beds have been considerably crumpled so that no general strike is observable. A sample of mica schist from the S. E. ¼ of N. E. ¼ sec. 6, 63–8 is numbered 482. Syenite gneiss from the N. W. ¼, N. E. ¼ sec. 6, 63–8 is 483.

The west side of Round lake has syenite around the shores. This becomes dark and siliceous and changed into a peculiar rock that seems to have been affected by the proximity of some igneous rock or other metamorphosing agent. 484.

In the N. W. ¼, N. E. ¼ sec. 7, 63–8 the syenite lies under a hill of gabbro which has a bold face on the north side nearly or quite 100 feet high. This syenite is sometimes micaceous enough to be called hornblendic gneiss. It has been somewhat broken up here and the contact between it and the gabbro is not visible. The latter rock is somewhat finer near the contact with the syenite than at the top of the hill. Syenite is represented by 485: the gabbro by 486.

In the S. E. ¼ sec. 6, 63–8 the rock is mica schist hardened by the vicinity or contact of the gabbro. The gabbro ridge runs south of the lake and really does not appear at any point on the lake shore. Samples of mica schist from the above-mentioned

locality are 487. Some of it is flinty and has very little if any mica in it.

To the northeast of the last is a knoll of fine red quartzyte or syenite. It is probably part of a large intrusion in the mica schist. 488.

The mica schist in the southeast part of section six is much twisted and varies greatly in its strike and in the composition and texture of its strata. Some are hard and siliceous and others are soft and iron-stained. It is cut by numerous veins or intrusions of granite and is slightly conglomeritic in places.

TOWNSHIP 63–9.

On the portage trail from Snowbank lake to the Kawishiwi river gneiss and mica schist are seen in a few outcrops within three-quarters of a mile from Snowbank. About a mile from the lake the trail passes within ten feet of a bluff of gabbro which faces east. This is in the S. W. ¼ of S. W. ¼ sec. 11, 63–9. The rock is the regular coarse labradorite gabbro. About 200 paces south of this gabbro, on the section line between ten and eleven is found a ridge of biotite, olivine schist. This has the usual strike, N. 60° E. and dips S. 75°. It is conglomeritic in many places and bears a striking resemblance to the conglomeritic mica schist found at the southeast corner of Disappointment lake. 504.

A ridge of gabbro is again crossed 450 paces south of the N. W. corner sec. 14, 63–9. This is a high ridge with a steep bluff of the coarse light-colored gabbro on the north side. Three hundred paces farther south the rock is all "muscovado" in a great ridge. No structure or bedding of any kind is visible in it. It is simply in large hills and ridges, and is fine-grained and homogeneous in texture.

A short distance north of the "quarter-post" between sections 14 and 15 this ridge of muscovado is bounded on the south by a swamp. Along the south side of the ridge, next to the swamp, is a considerable deposit of magnetite. It is the regular coarse, dull-lustred, gabbro magnetite. The rock can not be distinguished from the gabbro nor from the muscovado either. Number 505 is the muscovado. 505 A is the magnetite.

The Kawishiwi is about 12 feet above Snowbank lake where the portage from the lake strikes it. The trail passes across and by the side of gabbro ridges for half a mile before reaching the river.

Going north on the west line of sec. 16 the gabbro disappears a short distance north of the river. The rock next north of the gabbro is the muscovado-like mica schist with the usual strike and vertical dip. It is conglomeritic a short distance farther north and is hornblendic like that on Disappointment lake. It loses its similarity to muscovado and becomes regular mica schist, though more or less gneissic and conglomeritic, about the west "quarter-post" of sec. 16. Sample is 506.

At 340 paces north of the "quarter-post" mentioned above, a swamp intervening, a ridge of diabase is encountered. This runs along the north side of the swamp in a N. E.–S. W. course. It is probably part of the same diabase eruption as that east of Disappointment lake, 507. Many fragments of porphyritic conglomerate are seen lying about on the surface at this place.

This ridge keeps on rising with a gentle slope until its summit is reached at the N. W. corner of section 16. From here the descent is gradual toward the north, but not so gradual as on the south side. The diabase is massive for some distance from the place where it was first seen. Then it begins to show a coarse schistosity and has a coarse agglomeritic appearance as in the rock at Ely, the boulders being all of greenstone and indistinctly outlined on the surface. The rock is strikingly similar to the Ely rock as far as the agglomeritic appearance goes; but is not soft and chloritic like that, nor does it appear to be calciferous. It is simply regular diabase, 508.

At 375 paces north of the southwest corner of section nine the diabase has changed from a massive rock to a fine, schistose, diabase agglomerate. The direction of the very evident schistosity as well as of the lenticular pebbles of greenstone in it, is E. 16° S. This is on the northern slope of the great diabase ridge, and the rock has been examined at many places so there is no doubt as to its being part of the same diabase. The coarse agglomerate has become a fine schistose pudding-stone and is rapidly changing into green chloritic schist toward the north. Samples of diabase conglomerate are No. 509.

This fine greenstone agglomerate continues to be exposed for some distance toward the north. The direction of the schistosity swings around to N. W. and S. E. which is the general direction of it in sections 8 and 9.

Some distance south of the east "quarter post" of sec. 8 a ridge of porphyritic rock which contains grains of vitreous quartz is encountered. It is a light colored rock and when first

seen it appears perfectly massive. It has an abrupt contact with the diabase which is also more massive at this place. The porphyry appears to run in N. W.-S. E. ridges. North of here it is seen to be mixed up in every way possible with the diabase and finally, in the N. E. ¼, N. W. ¼ sec. 8, becomes the prevailing country rock.

Toward the north still farther this porphyry becomes coarsely schistose and acquires more of the green uncrystalline elements. It also loses its decidedly porphyritic aspect as the distance from the diabase ridge increases. It is slightly conglomeritic; in one place red jasper was seen in it and in another a pebble of greenstone. Nos. 510, 510 A and 510 B show these various conditions of the porphyritic rock.

The diabase continues to abound and ridges of porphyry, or porphyrel and greenstone are strangely mixed up together. In the N. E. ¼ sec. 8 are seen large ridges of jaspilyte, consisting of red and black jasper, hematite and magnetite in crumpled vertical beds running about N. 60° E. After a long and extensive examination the state of affairs seemed to be as follows: There is a large amount of this jaspilyte here. Some of these lenticular masses of jasper and iron ore were traced continuously for half a mile or even more. These masses lie in the diabase and have an abrupt contact with it. Many pieces and masses of jaspilyte of all sizes from that of a pea to the large ridges spoken of above are seen to be enclosed in massive or only slightly schistose diabase, not in any general line of strike, but at intervals separated from each other across the strike by various distances less than a mile.

Sometimes the diabase is quite coarse and appears more like dioryte with white feldspar crystals on the surface.

In some places the porphyry approaches quite near to these jaspilyte masses; but that is not to be wondered at, inasmuch as the ridges of porphyry run all through the diabase without any definite order or direction. This jaspilyte is more hematitic toward the north and west where it is identical in appearance with that at Tower. Places were seen where the diabase is quite schistose at the contact with the jaspilyte and even as soft and greasy feeling as the soft schists in some of the Tower mines. The beds of jaspilyte are nearly as much distorted as at Tower. This diabase is seen on both sides of the iron ore and cutting across the beds. It also seems to contain fragments of the porphyry and becomes porphyritic itself in the vicinity of the

porphyry ridges. Specimens of the diabase, which is found enclosing the large and small masses of jaspilyte in the N. E. ¼ sec. 8, are 511. Contact specimens with the jasper are 511 A. Samples of diabase containing small masses of jaspilyte are 511 B. Porphyritic diabase containing a piece of porphyry is 511 C. Samples of the soft sericitic or talcose rock are 512. This rock being so soft is always found in low places and could not be seen to be certainly part of the diabase. Sometimes the rock next to the jaspilyte is not green and does not look like diabase but is gray and somewhat schistose, 513. Samples of the jaspilyte are seen in 514.

The porphyry becomes more and more prevalent toward the N. E. "forty," sec. 8 until there is no more diabase nor jaspilyte. There is, however, a dyke of green trap that runs under Hugh Copeland's cabin in the N. W. ¼, N. E. ¼ sec. 8. It is about 30 inches wide and can be traced for 200 paces or more running about north and south through the porphyry. It is not perfectly straight but curves some and is faulted in two or three places. The course of it is also interrupted at one place north of the cabin by strings and branches from the porphyry mass which make it appear as if they both were plastic about the same time. Sample of the porphyry is 515. The dyke rock is 516.

The above observations are considered to be of importance as they seem to prove beyond doubt that *the jaspilyte beds are enclosed in basic rock of igneous origin.*

This region and these beds of iron ore contain some of the most promising deposits seen during the past season. There is good reason for believing that there are valuable and extensive beds of iron ore in the northern part of this township.

The ridges of diabase and porphyry alternate southeast of Copeland's cabin. A sample of rock composed of a tenacious green mineral is 517.

In some places the diabase is agglomeritic in close proximity to the enclosed masses of jaspilyte, the diabase all around such a mass containing the forms and outlines of greenstone pebbles. There is also conglomerate closely interbedded with this diabase agglomerate and apparently of a later date. It has for a magma the earlier fine agglomerate (?). These two sometimes come into direct contact, standing side by side. No. 520. This later conglomerate contains almost exclusively fragments of the por-

phyry and of the jaspilyte. It is never very thick and generally lies between the greenstone and the porphyry.

There are occasional tendencies toward a micaceous nature in the porphyry, and a thin stratum of schist bedded by sedimentation is seen here and there, 518.

Some of the fragments of jaspilyte seen enclosed in the greenstone are perfectly white jasper or quartzyte which crumbles into fine grains upon hammering, 519. This also is like the same fine granular quartz beds in the jaspilyte north of Tower.

In only one place was the iron ore and jasper seen in contact with the porphyry. At this place a bed of jasper three inches thick has porphyry on one side and diabase on the other. They come very close together in many places, but in all other cases observed there was a thin wall or flow of diabase between them.

A vertical bluff of greenstone 20 feet high was seen in one place with a thin coating of the light colored porphyry plastered over the entire face of the bluff. A contact specimen from here is 521.

In one place the coarser diabase which when weathered shows small white feldspar crystals on the surface, was cut by a small trap dyke. The coarser, older diabase is 522. The dyke rock is 522 A.

Going north on the line between sections nine and ten the first rock is seen quite near the river. This is fine-grained mica schist which may contain olivine, 523. This rock is conglomeritic in places and particularly in a small ridge not far north of the river. The small enclosed pebbles are compressed with their longer axes pointing N. W. – S. E., 523 A. There is next a ridge of diabasic mica schist, 523 B.

Some of the beds of mica schist are siliceous and felsitic and are iron-stained, 524. At 300 paces north of the S. W. corner sec. 10, there is quite a ridge of mica schist. It strikes N. W. and dips S. W. 70°. Samples showing lines and bands of sedimentation are 525. At 400 paces there is a contact between the beds of mica schist and diabase which latter has been more or less affected by the proximity of the schist and has a less massive appearance than usual. The mica schist too has been somewhat altered; but the change is abrupt and distinct between the mica schist on the S. W. and the greenstone on the N. E.

In this place therefore the mica schist has an abrupt contact with the greenstone and does not grade into it as it appeared to on the east side of Disappointment lake. The schist here seems

to have been affected by the greenstone eruption: its strike and schistosity have been bent around nearly 90° from the usual direction. The mica schist has been hardened and rendered more like the diabase so that upon a casual inspection the two might seem to run together. Mica schist from the contact is 526. The diabase is 527. A specimen of peculiar, dark mica schist which has gray figures and lumps like drops of mud all over the surface is 526 A.

This was not the main ridge of diabase but only a subordinate branch or large dyke of it. The mica schist and greenstone seem to have had quite a struggle for supremacy in this region; first one prevailing and then the other. The general strike is N. W. and the dip varies from S. W. 45° to vertical. There is a ridge of coarser diabase in the N. W. ¼, S. W. ¼ sec. 10. It is quite near a contact with mica schist. 528.

In many places the mica schist is full of light gray grains of soft material which weather out and leave the surface of the rock pitted with small holes. This schist is darker and less micaceous than some of the rest, but it always conforms with the general strike and seems to be a part of the general mica schist formation. 529.

The mica schist contains thin beds of green diabasic rock which run with the other beds and are also schistose. These beds are decidedly basic and only a few inches thick, but are quite persistent and maintain their general appearance and width as far as they can be followed. 530.

Going farther north the mica schist becomes harder and more feldspathic and appears to be incipient porphyry, showing how the extensive porphyry belt north of here may be altered mica schist. 531.

Some specimens of agglomeritic diabase in which the pebbles seem to have been pasted together in a very plastic state are 532. The mica schist and incipient porphyry have also a conglomeritic structure though it is rather indistinct.

A little jaspilyte is found enclosed in the greenstone in the N. W. ¼, N. W. ¼ sec. 10. The diabase is softer and chloritic and possesses the coarse agglomeritic or concretionary (?) structure seen in it so often.*

The observations made in going north on this section line simply confirm those made on the line a mile west, and demonstrate that the coarse, chloritic, schistose agglomerate is part of this

* Report of H. V. Winchell. Fifteenth annual report, p. 404.

great diabase eruption and that the jasper and iron ore beds are contained in it.

A ridge of mica schist is again encountered just south of the quarter post between sections 3 and 4. A large exposure of this rock is found here. It is quite hard and contains a little of the diabasic rock in these beds. 533. Strike is N. 16° W.

At the N. E. corner sec. 4, the porphyry is met with, and is the same in appearance as that found in the N. E. ¼ sec. 8. The relation between the porphyry and mica schist is not evident here, but they seem to have a more or less abrupt contact. Samples of porphyry are 534. The mica schist has been becoming more argillaceous and less micaceous. Here there is a large ridge of it in which the strata are greatly crumpled and the principal strike has been changed to N. 10° E. It here seems that the porphyry is not a part of the mica schist formation, but that it was protruded into the schist beds and caused all of this disturbance. Argillitic mica schist from here is 535.

Going west from here along the north line of sec. 4 a swamp is crossed, and on the west side is found a diabase ridge. Just west of the north quarter post of sec. 4 is more porphyry in knolls and ridges which penetrate and are surrounded by the diabase. They always have an abrupt contact. This porphyry is conglomeritic, containing felsitic and siliceous boulders a foot in diameter. Samples from the S. E. ¼, N. W. ¼ sec. 4 are 536. A basaltic structure is frequently seen in the porphyry.

In the S. W. ¼, N. W. ¼ sec. 4, on the ridge which lies between two small lakes is quite an exposure of red jasper and hematite. This is seen to be in beds of various thickness up to four or five feet, which do not have a common strike. Some strata, enclosed in diabase, strike east and west; while other beds only a few rods away strike E. 30° S. The beds all stand vertical and *are very little crumpled*, 537.

The diabase has a tendency to become coarsely schistose where it lies in contact with the iron and jasper, but farther away it is very hard, tough and massive. It has also a coarse agglomeritic structure, very indistinct at this precise spot, but quite noticeable a short distance east of here, and is chloritic. Nos. 538–538 C represent these rocks.*

* An analysis of this green rock, 538 B, made by Mr. C. F. Sidener shows, as was expected, that it is basic. The full record is as follows:

Silica, SiO_2	50.47 per cent.
Alumina, Al_2O_3	18.45 per cent.

There is also some black jasper and magnetite at this place enclosed in the greenstone in the same manner. The beds are thicker and seem to contain purer ore than the hematite beds. No. 539.

Between the N. W. corner sec. 4 and the east quarter post sec. 8 a decided change takes place. The diabase around the south side and west end of the small lake on the north line of sec. 4 assumes a schistose structure which becomes finer and more universal toward the southwest. At first it is a fine agglomeritic diabase schist; then it becomes more and more siliceous until it is flinty and actually resembles the Knife lake rock. From this place, where the rock was found to be very siliceous, a set of specimens was procured from every outcrop south as far as the E. quarter post sec. 8. This siliceous schist stands in vertical beds which strike N. W.-S. E., and sometimes swing around to N.-S. The rock becomes more and more flinty until at the N. E. corner sec. 8 we have the regular siliceous schist of Knife lake. From here south to the E. quarter post sec. 8, this siliceous schist is seen to grade into the porphyry which was found there before. In one or two places the siliceous schist seemed to be going back to diabase; and ridges of diabasic schist and agglomerate were crossed on this line; but they seem to be part of the intruded diabase which comes into contact with this porphyry farther south. Thus we have diabasic schist and even massive diabase becoming siliceous and even flinty and then porphyritic, and finally coming into contact again with another part of itself farther south. Nos. 540-540 J show this transition.

Going east from the N. E. corner sec. 8, mica schist is met with at less than a quarter of a mile. It has an abrupt contact with porphyry. 541.

The mica schist seen in this township is fine-grained, almost always argillaceous, poor in mica, which is always in very small glistening scales, and generally hornblendic.

Sesquioxide of iron, Fe_2O_3	2.13 per cent.
Protoxide of iron, FeO	7.74 per cent.
Lime, CaO	6.61 per cent.
Magnesia, MgO	6.90 per cent.
Potassa, K_2O	.30 per cent.
Soda Na_2O	2.58 per cent.
Phosphoric acid, P_2O_5	traces.
Water, H_2O	2.34 per cent.
	97.52 per cent.

The mica schist formation becomes hornblendic and massive in the N. W. ¼, N. E. ¼ sec. 9. Fine dark syenite from same place is 542.

On the north side of the Kawishiwi river, on the line between sections 19 and 20 the mica schist is only two rods wide. On the north side of it is the coarse diabase agglomerate.

PRAIRIE RIVER FALLS.

A visit was made at the end of the season to Pokegama falls and the region of Prairie River falls for the sake of comparison with and verification of notes made previously.

No new facts were noticed, the report of last year containing all of the points which were noted this season.

Some work is being done east of the lower falls by Minneapolis parties who are searching for iron ore; although no large body of ore has yet been encountered, the prospect is encouraging.

Specimens of magnetic ore were seen at Grand Rapids which came from the property of Mr. Kearny situated about 45 miles north of Grand Rapids in Township 61–24. It seems to belong to the Keewatin and is reported to exist in paying quantities. The locality was not visited.

Mr. Chas. F. Howe, of Duluth, has explored for iron ore in Minnesota for several seasons and is very well posted on the geology of iron ores. He reports the magnetitic quartzyte of the Huronian outcropping in Twp. 59–18. It has the usual dip of about 10° to the S. S. E. and lies near the syenite which is north of it.

The facts and observations given in scattered detail in the foregoing notes if amplified and dicussed at length with all of the careful consideration which they merit would far exceed the limits assigned to this report. But a brief allusion to some points which seem to furnish clues to the solution of a few of the unsettled problems in the geology of this region may be made here without attempting anything like a full discussion or even mention of all the theories upon which the facts before us have a bearing.

The lowest or oldest formation to which these notes make any reference is probably the syenite and gneiss ridge constituting the Giant's range. Observations on this rock were made at various points between Hinsdale, on the Duluth and Iron Range railroad,

and Snowbank lake: also at a few localities in the vicinity on what is supposed to be the northeastward continuation of this range. The general characteristics of the rock of this ridge are quite persistent. The vertical foliation, the unusually large grains of bluish quartz which it contains and the general aspect of the orthoclase serve to remind an observer in the Gunflint region of the same features in the rock southwest of Birch lake. Mica, however, frequently replaces hornblende or *vice versa;* and sometimes both are present. Near the surface and for fifteen or twenty feet below, this rock has a reddish or pink color; but at a greater depth it is gray.

A coarse conglomeritic structure is noted in the syenite-gneiss of this range at Hinsdale. Lenticular masses of dark hornblendic rock are seen at all depths in the gray rock at the quarries. These masses are generally more than eight inches in length, and the direction of their longer axes is vertical or nearly so. There is sometimes a foliation or schistosity in these inclusions, and this also is vertical.

A series of vertical crystalline schists is generally found next the older crystallines in other parts of this region; but north and south of the Giant's range at Hinsdale are found exposures of the sericitic or chloritic schists of the Keewatin so close to the syenite as to make it seem improbable that any crystalline schists intervene between them here. If the high ridge is the middle of an anticlinal, as seems to be indicated by the presence of the vertical Keewatin schists on the south side of the ridge, having the same strike as those on the north, what has become of the crystalline schists which lie next above the granites and syenites? Were they so highly metamorphosed and affected by pressure to such an extent that they were incorporated into the more gneissoid rock beneath them, or were they not a widespread and universal deposit? Were there elevated portions of the sea-bottom which were not covered by the sediments from which have resulted the crystalline schists, but which were later covered by the sediments of the Keewatin age? Considering this ridge to be the back-bone of an anticinal the latter supposition seems more probable.

If this be not an anticlinal how can the presence of such an extensive range of crystalline rock in the midst of greenish, chloritic, more or less argillaceous and siliceous schists be accounted for? If the vertical foliation be evidence of some former bedding structure, the only way to explain it seems to

be on the supposition that a portion of these schists themselves were metamorphosed by some unusual disturbance along the line of this range, either by the proximity of some great vent below or intense pressure at this place combined with chemical and hydrothermal forces.

The next formation is that already mentioned, the crystalline schist or Vermilion series. I wish to call attention to the fact that in Twp. 63–9 this series of rocks is found to be conglomeritic over a wide area, and has been rendered hard and porphyritic by some adjacent eruption, probably that great diabase outburst of the Keewatin age. Boulders of a large variety of rocks are seen enclosed in the mica schist around Disappointment lake. This fact alone serves to distinguish it from the diabasic agglomerates in which all of the pebbles, with hardly an exception, are of greenstone and jaspilyte.*

In connection with the crystalline schists "muscovado" should be mentioned. It seems probable that this term has been employed in the 15th and 16th reports of this survey, to designate the rotted granular condition of two or three different rocks. Dr. Alexander Winchell has applied it to a rock which he identifies with the Animike. It seems to have been used also to describe fine decayed gabbro as well as an altered condition of gneiss and the mica and hornblende schists.

As far as my observation goes it has been found quite easy to recognize decayed, rusted Animike and fine rotted gabbro such as is frequently found at the northern edge of the gabbro overflow. But in several localities, notably on the south shore of Disappointment lake, there are found large exposures of a granular, yellowish-brown rock which does not possess any distinct signs of bedding or schistosity and which yields to a blow of a hammer much as semi-hardened putty would. It contains fine scales of biotite and grains of feldspar and olivine. It lies at the north edge of the gabbro in rounded knolls which resemble gabbro hills at a little distance, and when its direct connection with the surrounding rock is obscured it can not be recognized as belonging to any of the usual formations of the region nor as being anything but "muscovado."

On the south shore of Disappointment lake there is a great deal of this rock. To the south of it are masses of olivinitic

* In his report on the Lake of the Woods, Geol. of Can. CC., Mr. A. C. Lawson says that the agglomerates of that region grade into conglomerates along the strike of the formation. This has not been observed to be the case in Minnesota.

iron ore standing in nearly vertical beds, capped with fine, decayed gabbro and having coarse labradorite gabbro on the south of it. Fortunately the lake shore affords a nearly continuous exposure, of this rock in both directions in the line of strike. It was here traced very carefully, on two different occasions, and was found to pass by insensible gradations into mica schist which became more and more micaceous and typical as the distance from the gabbro increased. This mica schist is the northeastern extension of the crystalline schists which are found north of the Kawishiwi river in townships 63–9 and 63–10, and have been followed continuously from there to this lake. The syenite of the Giant's range is known to have formed the northern shore of the Animike ocean. This range is low and narrow at this place and the Animike evidently was deposited on top of the syenite and up to or perhaps upon some of the mica schist which lies to the north of the syenite. Then came the gabbro eruption and overflow and with it a crumpling of the strata and uptilting of the Animike beds. The gabbro also altered the mica schist where it lay upon it, to muscovado, destroying the schistosity and bedding and even altering the mineral constituents of the rock, heating them so that they formed new combinations, the iron and magnesia of the biotite combining to a large extent with the free quartz to make olivine, though there are some minute scales of biotite left. The same explanation of muscovado appears to answer in other places where it was seen. It seems, therefore, that the term "muscovado" is rather an ambiguous one but would be more appropriately applied to mica schist altered by gabbro than to iron-bearing Animike rock.

Conformable with the crystalline schists are the grauwackes, chloritic schists, diabasic schists and siliceous schists of the Keewatin series. The foregoing notes give numerous detailed facts which it was my good fortune to observe in localities particularly rich in instructive geological phenomena. These facts have a decided bearing on the nature and origin of the Keewatin group and the iron ores and associated jaspilytes which are enclosed in it.

In townships 63–9 and 64–8 immense ridges of diabase and basic agglomerates were found. These form a part of the Keewatin formation. They pass conformably into the siliceous and argillaceous schists of that series, and become themselves soft, greenish chloritic schist which retains but slight resemblance to

the massive eruptive rock into which they grade and of which they are a part.

In the *American Geologist* for January, 1889, the writer gave a short resumé of the conclusions which had been reached as to the origin of these basic portions of the Keewatin. The observations which forced him to the conclusions there stated were made but a short time before; and when the article was written the fact that Mr. A. C. Lawson of the Canadian geological survey had described similar rocks in the Keewatin of the Lake of the Woods and had termed those aggregations in which the boulders are of the same material as the magma, "agglomerates" was unknown to him. Mr. Lawson also had previously offered an explanation similar to that given by the writer, of the surprising gradations observed between eruptive and fragmental rocks, viz., an alternation of "volcanic ejectamenta (both flows and tuffs) and aqueous sedimentation."

Dr. G. M. Dawson had also presented the same views and says in speaking of similar rocks in the vicinity of the Lake of the Woods, "Volcanic action would appear to offer the most reasonable explanation of their origin and distribution." *

These observations appear to parallelize our green chloritic and diabasic schists and agglomerates very closely with those of Mr. Lawson's original Keewatin. We find in them the same lenticular, basic fragments, the same "concretionary?" and associated amygdaloidal structures and the same transitions into siliceous, fragmental rocks.

It is gratifying to know that the views of these experienced geologists confirm the conclusions mentioned above. The opinion primarily held by the geologists of the Minnesota survey, with the possible exception of N. H. Winchell, and which view is still maintained by Dr. A. Winchell in the 16th Annual report, was that these rocks were of sedimentary origin and that the semi-crystalline, diabasic character was the result of intense metamorphism. The view now held is not wholly in conflict with that. It admits that portions of the Keewatin formation were purely sedimentary; but claims that the larger part of it consists of a mixture of eruptive and sedimentary materials, and is in many places extensively and wholly igneous.

In the opinion of the writer this has considerable bearing on the question of the origin of the jaspilytes embraced in the green schists of the Keewatin. They are supposed to be of some

* Geol. and Resources, Forty-ninth Parallel, p. 52.

sedimentary formation which was broken up and involved in the eruptions of Keewatin age. The masses of jaspilyte are angular and have abrupt contacts with the basic schists; they are highly siliceous and are of all sizes and shapes. When the masses are large they are usually in vertical position and somewhat elongated in the direction of the schistose structure in the surrounding rock. Examples of a precisely similar disruption of a sedimentary formation and its involution in an eruptive ejection are given in the foregoing pages in referring to the masses of Huronian quartzyte and magnetite enclosed in the gabbro. In several places chalcedonic quartz similar to that in the jaspilyte of the Keewatin, was found as part of the Animike. This fact is an indication of the fragmental nature of the jaspilyte; as they cannot be separated from each other,—if one is sedimentary the other must be—and there is not much doubt that that in the Animike is.

The most recent fragmental formation found in northeastern Minnesota is the Huronian. Many observations were made upon a quartzyte belonging to this formation which seems to lie above the Animike slates and is the rock which contains the non-titaniferous magnetite. This quartzyte has been called Animike quartzyte: but seems to lie above the Animike proper. It is perfectly conformable with the slates and sometimes grades into rock which is feldspathic and argillaceous rather than siliceous. It was observed to lie unconformably upon the rock of the Giant's range in two or three places. The most interesting contact observed was where this rock—the semi-siliceous, feldspathic Huronian—is seen to lie unconformably upon the vertical Keewatin beds. This was announced to be the case by Dr. A. Winchell in the 16th report but no actual contacts were mentioned. Considering the greenstone upon which the Animike was found to lie west of Gunflint lake as Keewatin—which it undoubtedly is—three or more fine contacts of the Animike upon the Keewatin are reported in these notes. The significance of this fact has been pointed out before.

A peculiar transition was found south of the Giant's range, in sec. 13, 60–13, where the Animike is seen to grade downward into the syenite. The character of this transition, however, does not seem to be metamorphic, but rather fragmental. There seems to have been a certain amount of the loose, crystalline material which had resulted from the decay and erosion of the syenite lying on top of the solid rock in the bed of the sea. The

Animike sediments were deposited upon and around this syenite stuff. At first the material was mainly crystalline, the sediments forming but a very small part of the whole and only filling the cracks and cavities. A few feet farther up the materials were about evenly divided, the fine detritus filling large spaces between the elevated portions of the larger pieces of syenite. As the sediments increased and grew deeper the crystalline material was completely buried and no traces of the underlying rock were left except here and there a small fragment of syenite or an orthoclase crystal which came rolling in from above and settled down on the sediments. Sometimes these crystals are quite perfect and look strangely out of place in a rock which is so plainly sedimentary and so little altered.

As a rule there is a decided difference in the texture and appearance of the Animike and Keewatin rocks; the former having a smaller proportion of feldspathic and greenish, basic material, and usually containing more quartz and some magnetite. The slates too of the Animike are darker and appear to be carbonaceous; while the slates and schists of the Keewatin are argillaceous and hydromicaceous. These differences are so general that a person who has spent a season comparing and examining these rocks can usually tell at a glance to which formation a specimen belongs. In the vicinity of the east end of Gunflint lake, however, the Animike has a marked resemblance to the Keewatin and it is difficult to distinguish them. They both have somewhat the appearance of grauwacke and are less schistose and slaty than usual. They are of a dark gray color, have a rough surface on fresh fracture and show fewer bands of sedimentation than elsewhere. The Animike, however, contains fine grains of magnetite disseminated through it with a tendency toward a banded arrangement, and the Keewatin has none.

Although the Huronian quartzyte with which is associated the non-titaniferous magnetite lies unconformably upon the syenite of the Giant's range it is believed to lie above the Animike slates and to rest conformably upon them. The rock which was deposited at the border of the ocean upon the syenite seems to have been more siliceous than those portions of the same strata which were farther from the shore. Thus the rock which lies directly upon the syenite would be a quartzyte and would pass into the less acidic rocks farther south. This condition of things is believed to have been observed in Twp. 60-13. Still there is

probably an extensive quartzyte which is later than the Animike and which lies directly upon the syenite because the land was slowly becoming more submerged and the sediments kept accumulating and extending farther and farther over the range of rock which constituted the northern limit to the ocean and the strata formed in its depths. The dip of the quartzyte corresponds with that of the slates wherever seen, and although the latter were not seen at any place underlying the former, yet their relative positions and mutual relations seem to indicate that they do so.

The gabbro has been so fully discussed in previous reports of this survey that it is necessary to say but a few words concerning it. The fact that it is found to embrace large fragments of the Huronian quartzyte and slates proves it to be of later origin. It is intersected by dykes of greenstone which are of still more recent date,—perhaps of the Cupriferous age, as that is said by the State Geologist in the Tenth annual report, p. 112, to be of more recent date than the gabbro. However, the appearance of these rocks in sec. 35, 58–6 gave me the impression that the gabbro is on top of the Cupriferous and hence more recent.

A coarse basaltic structure was seen in the gabbro on the south side of Tucker lake. There was also an appearance of sedimentary structure in the gabbro in N. W. ¼ sec. 2, 64–3, caused by parallel bands of magnetite several feet in length. It shows how one may be deceived by similar banded structure in other places.

Coarse hornblende, believed to be the largest ever found in this state, was found in the gabbro in the S. E. ¼ sec. 25, 63–10. Crystals six inches long were obtained. Many seen in the same place were even larger.

LIST OF SPECIMENS COLLECTED BY H. V. WINCHELL DURING THE SUMMER OF 1888.

354. Hydrated hematite. John Mallmann's working. Sec. 29, 59–14.

354 A. Gray, feldspathic rock, to which is attached a pebble(?) of hematite. Same locality.

355. Gray rock containing magnetite. Short distance west of last.

355 A. Gray rock containing limonite. From main shaft at same place.

356. Magnetitic chrysolyte. 400 paces east of the W. ¼ post sec. 10, 60–12.

357. Syenite. S. W. ¼ sec. 8, 60–12.

358. Olivinitic magnetite. One-fourth mile south of N. W. corner sec. 17, 60–12.

359. Greenish, magnetitic, olivinitic quartzyte. S. W. ¼, S. W. ¼ sec. 17, 60–12.

360. Dark, siliceous magnetite. N. E. corner sec. 19, 60–12.

361. Slaty, carbonaceous rock. Same locality.

362. Stratified magnetite and quartzyte or siliceous schist. N. W. ¼, N. E. ¼ sec. 19, 60–12.

363. Magnetite. N. W. ¼, N. E. ¼ sec. 19, 60–12.

364. Quartz conglomerate with a green matrix. From boulders seen east of Iron lake. N. W. ¼ sec. 24, 60–13.

365. Hornblendic Animike slate. A short distance north of last locality.

366. Samples showing the transition from Animike to the syenite of the Giant's range. North end of Iron lake, S. W. ¼ sec. 13, 60–13.

367. Greenish Animike rock containing a felsitic boulder. Same locality.

368. Coarse, micaceous syenite, N. E. ¼ sec. 14, 60–13.

369. Black, magnetitic rock, S. W. side of Iron lake. N. E. ¼ sec. 23, 60–13.

370. Tough, dark magnetitic rock. N. W. ¼ sec. 35, 60–13.

371. Reddish-gray quartzyte. Found in fragments on the trail in N. W. ¼ sec. 32, 60–13.

372. Samples from the bottom of the Animike where it passes into and rests upon the syenite. South of the trail. S. W. ¼, N. W. ¼ sec. 32, 60–13.

373. Black, carbonaceous slate rock containing magnetite. S. W. ¼, S. W. ¼ sec. 32, 60–13. From a shaft.

374. Grayish rock containing bands of magnetite. A little N. W. of last.

374 A. Reddish, jaspery rock. Same locality.

375. Weathered samples of magnetitic rock. S. W. ¼ sec. 31, 60–13.

376. Sample of reddish, decomposed jaspery rock from top of a shaft in N. E. ¼ sec. 11, 59–14.

376 A. Hematitic rock from bottom of the same shaft.

377. Feldspathic Keewatin schists. N. W. ¼ sec. 11, 59–14.

378. Feldspathic, gray, Keewatin schist, S. E. "forty" sec. 11, 59-14.

379. Olivinitic, magnetitic rock. From a shaft in N. W. ¼ sec. 14, 59–14.

380. Dark, slaty rock containing needle-shaped crystals of hornblende and bands of black jasper. Sec. 22, 59–14.

381. Grayish, soft, sericitic schist, S. E. ¼ sec. 17, 59–14.

382. Gray syenite of the Giant's range, Hinsdale.

382 A. Red syenite containing decayed hornblende. Found near seams or faults in the syenite at Hinsdale.

383. Hornblende schist from included boulder-forms in the syenite, Hinsdale.

384. Fine, gray granite, found cutting the syenite at Hinsdale.

385. Dark, red, decomposed syenite. Three miles north of the Giant's range on the railroad.

386. Gabbro. Sec. 5, 58–14. In a railroad cut three-fourths of a mile north of Beaver creek.

387. Dark, silico-argillaceous rock apparently carbonaceous. N. E. ¼, S. W. ¼ sec. 9, 58–14. On Partridge river.

388. Reddish, hematitic, quartzose rock. From a shaft in N. E. ¼, S. E. ¼ sec. 11, 59–14.

389. Feldspathic Keewatin schist. Near the centre of S. E. ¼ sec. 11, 59–14.

389 A. Quartz from veins in last. Containing talc.

390. Dark, carbonaceous (?) rock supposed to be Keewatin. Same locality.

391. Felsitic siliceous schist. N. E. ¼ sec. 15, 59–14.

392. Magnetic, olivinitic iron ore, about 200 paces southeast from last and 40 feet higher.

393. Magnetic iron ore. N. W. ¼, N. W. ¼ sec. 14, 59–14.

394. Pinkish quartzyte. Found in angular fragments on the trail in Twp. 60-13.

395. Black magnetic sand. Birch lake, S. W. ¼, S. E. ¼ sec. 32, 61–12.

396. Fine, muscovado-like gabbro. N. E. ¼ sec. 26, 61–12.

396 A. Specimen of a boulder (?) enclosed in last.

397. Animike or Huronian quartzyte. S. E. ¼, N. E. ¼ sec. 26, 61–12.

397 A. Hornblendic quartzyte. Same locality as last.

397 B. Quartzyte containing unknown mineral. Same place.

397 C. Magnetitic quartzyte. Same locality.

398. Stratified quartzyte and magnetite. S. E. ¼ sec. 26, 61–12.

399. Olivinitic quartzyte. E. ½, N. W. ¼ sec. 35, 61–12.

399 A. Coarse quartzyte and magnetite. Same locality.

400. Syenite, pink and rather coarse. S. E. ¼, N. E. ¼ sec. 35, 61–12.

401. Quartzyte, containing much magnetite. Same locality.

402. Hornblendic, olivinitic magnetite rock. N. E. ¼, S. W. ¼ sec. 35, 61–12.

403. Coarse quartzyte and fine chrysolyte. S. W. "forty," sec. 35, 61–12.

404. Chrysolyte. S. W. ¼ sec. 35, 61–12.

405. Olivine bearing magnetitic quartzyte. N. ½, S. E. ¼ sec. 24, 61–12.

405 A. Hornblendic samples of last.

405 B. "Slickensides." Same locality.

406. Hard, hornblendic Animike found lying upon syenite. S. E. ¼, N. E. ¼ sec. 35, 61–12.

407. Magnetite and quartzyte in banded alternation. S. E. ¼ sec. 30, 62–10.

408. Granular olivinitic rock. Same locality.

409. Fine grained olivinitic magnetite. Same locality.

410. Titaniferous (?) magnetite. Same locality.

411. Hornblendic olivinitic quartzyte. Same locality.

412. Coarse gabbro. S. E. ¼, N. E. ¼, sec. 36, 63–10.

412 A. Coarse hornblende and labradorite. Same locality.

413. Altered Animike from fragments enclosed in the gabbro. Same locality as 412.

414. Coarse magnetite. Same place.

415. Very coarse hornblende. From the gabbro. S. E. ¼, S. E. ¼ sec. 25, 63–10.

416 and 416 A to 416 E represent a transition from sericitic schist to granite.

417. Micaceous hornblendic schist. Same locality.

418. Biotitic hornblendic schist. N. W. forty sec. 4, 63–12.

419. Calciferous sericite schist. N. W ¼ sec. 4, 62–12.

420. Gabbro from lake Isabelle. N. W. ¼, S. E. ¼ sec. 35, 62–8.

420 A. Gray, fine granular rock contained in last.

421. Pebbles from a point just east of last.

422. Dyke rock. S. W. ¼, S. E. ¼ sec. 36, 62–8.

423. Fine, brown gabbro containing biotite. East of lake

Isabelle in T. 62–7.

424. Gray labradorite rock. Two miles up Swamp-lake river from lake Isabelle.

424 A. Gray gabbro with a streak of red in it. Same place.

424 B. Red gabbro. Same locality as last two.

425.
425 A.
425 B.
425 C. } Specimens illustrating a change from gabbro to dark, tough hornblendic rock.

426. Hornblendic gabbro. East of the north end of lake Harriet.

427. Gabbro. From a small island near the south end of Nine Mile lake.

428. Gabbro. From west side of Crooked lake.

429. Trap rock. Sec. 15, 59–6. West of the narrows.

430. Fine grained, olivinitic gabbro. West side of Nine Mile lake.

431. Gabbro. Sec. 35, 58–6.

432. Red, impure felsyte. East of last a few rods.

433. Siliceous Keewatin schist. About 40 rods up the creek which enters the east end of Gunflint lake from the northeast.

434. Sericitic schist. Farther up the creek on east side.

435. Reddish, jaspery Animike rock. Bed of same creek.

436. Dark, ferruginous conglomerate. About one-fourth mile up the creek.

437. Greenish, sericitic schist. East of last a few rods.

438. Animike from near a contact with Keewatin. Bed of same creek.

439. Keewatin rock from same place.

440. Magnetitic gabbro. N. E. ¼, N. W. ¼ sec. 2, 64–3.

441. Dioritic magnetitic gabbro. S. W. ¼, N. W. ¼ sec. 2, 64–3.

442. Titaniferous magnetite. S. E. ¼, N. W. ¼ sec. 2, 64–3.

443. Black carbonaceous slate. N. W. ¼ sec. 35, 65–3.

444. Greenstone. Found lying on top of 443 (H).

445. Porphyry or porphyrel. Loose mass at same place.

445 A. Trap found stuck fast to 445.

446. Very strongly magnetic iron ore. N. W. ¼, N. W. ¼ sec. 23, 65–4.

447 and 447 A to 447 E illustrate a transition from Black Animike slate to greenstone. N. E. ¼ sec. 25, 65–4.

447 F. Porphyritic trap rock. Same locality.

447 G. Dyke rock. Same locality.

448. Brecciated Animike slate. Same locality.

449. Quartz conglomerate not seen in place. From sec. 28, 65–4.

450. Magnetite. N. W. ¼ sec. 28, 65–4.

451. Biotitic altered greenstone. Same locality.

452. Diamond drill cores. Same locality.

452 A. Pyritous quartzyte from bottom of Animike at same place.

453. Drillings from about one-eighth mile south of the "camp" in sec. 28, in 65–4.

454. Quartzyte and magnetite. N. W. ¼ sec. 35, 65–5.

455. Animike from next to a contact with underlying greenstone. N. W. ¼ sec. 35, 65–5.

455 A. Animike rock from a similar contact 150 paces west of last.

456 and 456 A to 456 C are samples of the greenstone from the eastern contact taken in order receding from the line of contact.

456 D is a sample of greenstone from the western contact.

457. Conglomerate greenstone. 250 paces east of last.

458. Fine, crystalline, grayish-brown rock composed of plagioclase, mica, olivine and magnetite. North of last in a high ridge.

458. A. Coarse, hornblendic gabbro. S. line sec. 12, 64–6.

459. Gabbro. Gabemichigama lake. N. E. ¼ sec. 6, 64–5.

460. Modified Animike. South side of the island in N. W. ¼ sec. 6, 64–5.

461. Magnetitic gabbro. S. E. ¼ sec. 1, 64–6.

462. Decomposed gray quartzyte. Under the gabbro at same locality.

463. Conglomeritic grauwacke. N. W. ¼ sec. 33, 66–6. South of Otter Track lake.

463 A. Rock resembling magma of Ogishke conglomerate. Same locality.

464, 464 A and 464 B illustrate the passage of grauwacke into flint.

465. Magnetitic siliceous schist. N.W. ¼,N. W. ¼ sec. 33, 66–6.

466. Magnetitic jaspery rock. On hill east of last.

466 A. Contact specimen between 466 and siliceous greenish Keewatin schist. Same locality.

467. Amygdaloidal calciferous rock from boulders enclosed in

green chloritic schist. North side of Otter Track lake. N. W. ¼ sec. 27, 66–6, as in Minn.

467. A. From similar boulders not amygdaloidal. Same place.

468. Calciferous breccia found immediately surrounding the boulder forms.

469. Jaspilyte. Short distance east of last.

469. A. Magnetite. Same locality.

470. Green schist from near a contact with 469.

470. A. Jasper from same contact.

471. Feldspathic, semi-crystalline schist. From the corner marked "R 333" and "R 337" about half a mile north of Otter Track lake.

472. Coarsely porphyritic green rock. North side of a lake which lies on the north side of Otter Track lake.

473 and 473 A. Keewatin rock turning into red and black jasper. North of Otter Track lake.

473 B. Magnetite in green schist. Same locality.

474. Jasper and magnetite. Same locality.

475. Average sample of the non-schistose Keewatin from north of Otter Track lake.

476. Argillyte. N. W. ¼, S. E. ¼ sec. 2, 64–8. Lake Vira.

477. Fine mica schist. S. W. ¼, S. W. ¼ sec. 32, 64–8. Between Snowbank and Disappointment lakes.

478. Red, fine syenite. Cutting last.

479. Mica schist. S. E. ¼ Sec. 32, 64–8.

480. Conglomeritic mica schist. Same locality.

480. A. Red granite from intrusions in 480.

481. Trap rock from a dyke cutting 480.

482. Mica schist. S. E. ¼, N. E. ¼ sec. 6, 63–8. Round lake.

483. Syenite gneiss. N. W. ¼, N. E. ¼ sec. 6, 63–8. Round lake.

484. Dark siliceous syenite. West side of Round lake.

485. Micaceous syenite. N. W. ¼, N. E. ¼ sec. 7, 63–8. Round lake.

486. Gabbro. Found lying on 485.

487. Hardened mica schist. S. E. ¼ sec. 6, 63–8.

488. Fine red syenite. Intrusion in last.

489. Finely conglomeritic mica schist. N. E. ¼ sec. 5, 63–8. Disappointment lake.

490, 490 A and 490 B represent a transition from mica schist to muscovado. N. E. ¼, S. W. ¼ sec. 4, 63–8.

490 C. Mottled muscovado. Same locality.

491. Olivinitic magnetite and quartzyte. Same place.

492. Fine gabbro found lying upon 491.

493. Coarse labradorite gabbro. South of last.

493 A. Titaniferous (?) magnetite. Found in last.

494. Feldspathic, muscovado-like mica schist. N. E. ¼ sec. 4, 63–8.

495. Fine, micaceous syenite. S. W. ¼ sec. 34, 64–8.

496. Conglomeritic mica schist. N. E. ¼ sec. 33, 64–8.

497. Diabasic conglomerate. From N. W. ¼ sec. 34 and S. W. ¼ sec. 27, 64–8.

498. Diabasic schist. Same locality.

499. Diabase. Same locality.

500. Gneissic schist from lake shore having a foliation from N. W. to S. E., N. W. ¼ sec. 34, 64–8.

501. Biotitic trap. S. W. ¼ sec. 27, 64–8.

502. Siliceous greenstone. N. E. ¼, S. W. ¼ sec. 27, 64–8.

503. Porphyritic mica schist conglomerate. S. W. ¼, N. W. ¼ sec. 27, 64–8.

504. Conglomeritic mica schist. S. W. ¼ sec. 11, 63–9.

505. Muscovado. North of quarter post between sections 14 and 15, 63–9.

505 A. Titaniferous (?) magnetite. Same locality.

506. Fine, gray, hornblendic mica schist. S. W. ¼, N. W. ¼ sec. 16, 63–9.

507. Diabase, 340 paces north of W. quarter post sec. 16, 63–9.

508. Diabase. N. W. corner sec. 16, 63–9.

509. Fine conglomeritic diabase. 375 paces north of the S. W. corner sec. 9, 63–9.

510. Porphyrelle. N. E. ¼ sec. 8, 63–9.

510 A. Porphyrelle containing red jasper. Same locality.

510 B. Porphyrelle containing greenstone. Same locality.

511. Diabasic rock found enclosing jaspilyte. N. E. ¼ sec. 8, 63–9.

511 A. Contact specimens of diabase and jaspilyte. Same locality.

511 B. Diabase containing fragments of jaspilyte. Same locality.

511 C. Porphyritic diabase containing fragments of porphyrelle. Same locality.

512. Soft talcose rock. Same general locality.

513. Gray schistose rock found in contact with jaspilyte. Same locality.

514. Jaspilyte (jasper and magnetite). Same locality.

515. Porphyrelle. N. W. ¼, N. E. ¼ sec. 8, 63–9.

516. Trap rock. Cutting last.

517. Rotted diabase. Southwest of last some distance.

518. Micaceous diabasic schist. Same general locality.

519. White, crumbling jasper. Sec. 8, 63–9.

520. Dark, ancient conglomerate in contact with the porphyrelloid conglomerate. Sec. 8, 63–9.

521. Contact specimen. Diabase and porphyrelle. Sec. 8, 63–9.

522. Coarser diabase than usual, having white crystals of feldspar on weathered surfaces.

522 A. Fine diabase cutting 522.

523. Fine grained olivinitic mica schist. S. W. forty sec. 10, 63–9.

523 A. Conglomeritic mica schist. Same locality.

523 B. Diabasic mica schist. North of last.

524. Rusty, decomposed mica schist. Same locality.

525. Mica schist showing stratification. At 300 paces north of the S. W. corner sec. 10, 63–9.

526. Mica schist from a contact between it and diabase. 100 paces north of last.

527. Diabase from same contact.

528. Diabase. N. W. ¼, S. W. ¼ sec. 10, 63–9.

529. Dark, pitted mica schist. Same locality.

530. Diabasic strata in mica schist. Same locality.

531. Porphyritic mica schist. North of last.

532. Diabase conglomerate. Same general locality.

533. Mica schist, somewhat diabasic. Just south of the quarter post between secs. 3 and 4, 63–9.

534. Porphyrelle. N. E. corner sec. 4, 63–9.

535. Argillitic mica schist. Same locality.

536. Porphyrelloid conglomerate. S. E. ¼, N. W. ¼ sec. 4, 63–9.

537. Jaspilyte. S. W. ¼, N. W. ¼ sec. 4, 63–9.

538. Diabase from contact with Jaspilyte. Same locality as last.

538 A and 538 B are from a distance of five and ten feet respectively from this contact.

538 C. A phase of the diabase which does not look so basic. Same place.

539. Black jasper and magnetite. Same locality.

Nos. 540 and 540 A to 540 J illustrate a transition from fine diabasic schist through siliceous argillyte to porphyrelle which takes place between the N. W. corner sec. 4 and the E. quarter post sec. 8, 63–9.

541. Mica schist. N. W. ¼, N. W. ¼, sec. 9, 63–9.

542. Fine, dark syenite. N. W. ¼, N. E. ¼ sec. 9, 63–9.

ELEVATIONS DETERMINED BY ANEROID BAROMETER BY H. V. WINCHELL.

	Ft. above L. Superior.
Devil's Track river at the crossing of the county road north of Grand Marais	1000
Top of "Pine Mountain," 12 miles from the lake	1550
South Brulé river at the crossing of county road	1000
Birch lake, Twp. 65–2	1220
Duncan's lake	1205
Rose or Mud lake	1060
South lake	1085
North lake	1085
Gunflint lake	1080
Loon lake	1275
Mayhew lake	1385

Lake Vira is about the same hight as Knife lake.
Ensign lake is 40 feet lower than Knife lake.
Snowbank lake is 45 feet higher than Knife lake.
Disappointment lake is 120 ft. higher than Knife lake.
Round lake is 90 feet higher than Knife lake.
Kawishiwi river is 57 feet higher than Knife lake where the portage from Snowbank lake strikes it. N. W. ¼ sec. 15, 63–9.

CONTACTS OBSERVED.

Animike on the syenite of the Giant's range, north of Iron lake; also west of Gunflint lake, N. W. ¼ sec. 23, 65–4; also S. E. ¼, N. E. ¼ sec. 35, 61–12.

Gabbro on Animike, N. E. ¼ sec. 26, 61–12 south of Birch lake; also south side of Disappointment lake. Gabbro on syenite, N. W. ¼ sec. 24, 61–12; also N. E. ¼ sec. 7, 63–8. Fine-grained gabbro or trap on Animike slate, east end of Gunflint lake, and around Loon lake. Animike on Keewatin, creek bed at east end of Gunflint lake; also N. W. ¼ sec. 35, 65–5; also N. E. sec. 25, 65–4.

Trap rock on porphyrel, Loon lake; also sec. 8, 63–9. Jaspilyte and porphyrel, Twp. 63–9, many places. Jaspilyte and diabase, many places in Twp. 63–9. Mica schist and diabase, S. W. ¼ sec. 10, 63–9. Mica schist and porphyrel, N. E. corner sec. 4, 63–9.

TRANSITIONS OBSERVED.

From Animike to syenite. North of Iron lake.

From Keewatin hydromica schist to granite. N. E. ¼ sec. 9, 63–12.

From black Animike slate upward to fine gabbro or trap. South side of Loon lake.

From black Animike slate downward to trap. N. E. ¼ sec. 25, 65–4.

From mica schist to "muscovado" and back to mica schist. N. E. ¼ sec. 4, 63–8.

From mica schist to diabase. N. W. ¼ sec. 34, 64–8.

From diabase through diabasic agglomerate to chloritic schist. Twp. 63–9.

From diabasic schist through siliceous schist to porphyrel. Twp. 63–9.

CONGLOMERITIC STRUCTURE OBSERVED IN

Keewatin, in schistose, porphyrelloid and diabasic portions.

Animike, in various places.

Syenite of Giant's range, at Hinsdale.

Mica schist and porphyrelloid mica schist. S. E. ¼ sec. 32, 64–8.

Gabbro, containing fragments of Animike. N. E. ¼ sec. 26, 61–12.

REPORT OF ULY. S. GRANT.

IV.

REPORT OF GEOLOGICAL OBSERVATIONS MADE IN NORTHEASTERN MINNESOTA DURING THE SUMMER OF 1888.

By Uly. S. Grant.

I. General Statement.

During the latter part of June, all of July, and the greater part of August a party was employed in collecting sets, of twenty-five specimens each, of the typical rocks of northeastern Minnesota. Besides the writer, the party consisted of Mr. A. D. Meeds, of the University, and two Indians, Charley and Nick Sucker, from Vermilion lake. The traveling was done entirely by canoe, as is usual in this region. The town of Ely, which is now the northern terminus of the Duluth and Iron Range railroad, was used as a supply point, and from here three trips were made eastward and south-eastward,— each trip taking about three weeks. Most of the country from Vermilion lake east to Gunflint lake, explored by the survey during the last two summers, was passed over, and rock samples collected from various localities designated by Prof. N. H. Winchell. The samples are of museum size — three by four inches — and bear the numbers given by Prof. Winchell in the tenth, fifteenth and sixteenth annual reports of the survey. In all forty-five sets, or over eleven hundred specimens, were collected; these, together with those collected in 1886 and 1887, form quite a complete series of typical rocks of that part of the state lying north of lake Superior. The specimens were shipped to Minneapolis and are now in the rooms of the survey,—but as yet they have not been unpacked and labeled.

While collecting the rock samples some attention was paid to the geology; thus a few additional facts were noted, and several

places, not before visited by the survey, were examined. But these observations were not very extensive, as the time was limited and the main object was to collect the samples wanted. This fact, together with the inexperience of the writer in the line of geology, will perhaps account for discrepancies in the following pages. The only place where any detailed observations were made was on the north shore of Gunflint lake while trying to discover the western extension of the belt of hornblende schists (Vermilion series) which lie between the vertical earthy schists (Kewatin) on the south and the gneiss on the north.

During the latter part of August, all of September and the first half of October the writer was engaged, under the direction of Mr. H. V. Winchell, in examining reported outcrops of iron ore. While thus employed, two separate trips were made,—one from Gunflint lake south to Brulé lake, and one along the Kawishiwi river in T. 63–7 and 62–9. A few notes, concerning the general geology of the country thus passed over, are given; but it should be remembered that the main object of these trips was to examine into the richness and extent of the iron ore outcrops. Notes on a few of the lakes passed through on a trip from Kawishiwi lake south to lake Superior are also given; but a full account of this trip will be found in the report of Mr. H. V. Winchell.

Owing to the numerous heavy spring rains, all the lakes and rivers were very high,—from two to five feet higher than during the summers of 1886 and 1887; this rendered examination of rock exposures along the lake shores more difficult than formerly, as in many cases the water extended back over the rocky shores to the soil. The insect pests (black-flies and mosquitoes) were also very numerous and troublesome.

The Canadian side of the boundary lakes and rivers from Gunflint lake to Ottertrack lake, seems to have been surveyed during the last year.

The rock samples, which illustrate the following notes, are numbered from 1 up to 298, the letter G being placed on each specimen, after the number. The figures are green,—paris green and shellac dissolved in alcohol being used.

The township, section and quarter section, where each specimen was found, is given. The township (in this report) is always north and the range west of the fourth principal meridian, Minnesota.

Appended to this report will be found (1) a brief summary of

observations, (2) a list, with notes, of the typical rocks of which 25 specimens were collected, (3) a table of barometric elevations and (4) a catalogue of rock samples to illustrate the writer's notes.

Magnetic bearings were taken roughly in the field; these have not been corrected either for general or local variations.

II. Geological Notes.

OTTERTRACK LAKE.

This is one of the boundary lakes, and extends north-east and south-west in T. 66–6. On the north shore of the lake in N. E. ¼ of N. W. ¼ sec. 27, T. 66–6 (if the Minnesota sections were extended northward to the Canadian shore) is a cliff about forty feet high; this cliff is composed of magnetic iron slates banded with red and black; the red bands are jasper and the black ones are composed mostly of magnetite. The banding is twisted and bent in every direction, but is almost always in a vertical plane. Mr. J. F. Conniff of Duluth tells me that on the south side of the lake in the N. ½ of sec. 33 (80 rods south of the lake shore), there is an exposure of these vertical iron slates; he says they appear in the form of a "vein," from four to twelve feet wide, and strike east and west. No. 1 and No. 2 are specimens he gave me from this locality; No. 3 is from the cliff on the north shore of the lake. The first outcrop on the shore west of these slates is represented by No. 4, and the first east of them by No. 5, both of which are graywacke-like rocks. A full account of this place will be found in the report of Mr. H. V. Winchell; also see the sixteenth annual report, p. 210, for the geology of Ottertrack lake.

GUNFLINT LAKE AND VICINITY.

This lake lies on the boundary in the north part of T. 65–3, and extends eastward into T. 65–2; it also touches the eastern side of T. 65–4.

On the small island in S. E. ¼ of S. E. ¼ sec. 13, T. 65–4, were found five elongated pieces of a dark schist, which is composed principally of hornblende and feldspar, the latter weathering pinkish; these pieces are in the syenite of which the island is composed; the largest piece was five feet long and seven inches

wide; the long axis of each piece extends in the same direction, —i. e. N. 85° W. (Mag.). All the pieces, except one, thin out into wedge-shaped ends. No. 6 represents the syenite, and No. 7 the schist. The largest of these pieces is shown in Fig. 1.

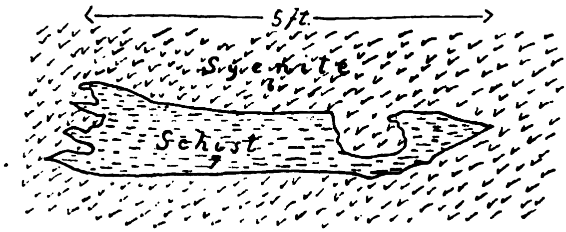

Fig. 1. Hornblende schist inclosed in syenite, Gunflint lake.

Sections north of Gunflint lake. Three sections were made north from the lake near the centre of the northern shore, the object being to discover what becomes of the hornblende schist belt (the Vermilion series of the survey) that was found north of the lake near its eastern end in 1887. If this belt continues in the same strike as there seen, it should appear again in Blackfly bay north of the narrows of the lake; but no trace of it is here found. The measurements in these sections are only roughly estimated, the ground being too rough and too much covered with underbrush to allow pacing. The location of the observations is given as accurately as possible, supposing the section lines of the Minnesota townships to be extended to the Canadian side. Fig. 2 shows the relations of this belt of crystalline schists and of the Kewatin slates to the syenitic gneiss. For the description of this belt of hornblende schists the reader is referred to the sixteenth annual report, pages 68–77, 262–6, 337, and the map on page 255.

SECTION I: North from the lake shore a little west of the line between secs. 14 and 15, T. 65–3. This would be directly north of the east end of the island in sec. 15—the only island in this part of the lake.

The first rock exposed is a vertical sericitic schist, on the lake shore; it extends east and west about 200 yards; this is the most westerly, but one, exposure of vertical schists on Gunflint lake. This rock is represented by No. 11; the exposure continues north 100 feet, and rises 8 feet above the water. After passing a swamp 250 feet wide, a hill rises 60 feet above the lake; this hill is composed of schist or slate similar to No. 11,

but it is growing harder and more flinty (No. 12); this hill is 200 feet across. Beyond is another swamp about 200 feet wide, and then rises a second ridge, 400 feet in width; the first exposure is of a fine porphyrelloid rock (No. 13) with small crystals of white feldspar; these crystals are arranged more or less in layers corresponding to the strike. The rest of the hill is composed of alternating beds of black slate (No. 16) and porphyrelloid rock represented by No. 13; the latter rock varies from that in which the feldspar crystals are quite conspicuous, ⅛ inch or more in diameter (No. 14), to that in which they are quite small (No. 15). Near the top of the hill and lying in a small depression is a mass of dark trap (No. 17); the contact between the trap and slate was covered by soil. Nearer still to the top of the hill are two dikes, one and four feet in width; these dikes run parallel with the beds of slate and are exposed for over 20 feet; in the larger are fragments of baked slate; and the outer portion of this dike is very much finer-grained (No. 18) than the inner (No. 19); Nos. 18 and 19 seem to be about the same as No. 17. On the summit of the hill in the porphyrelloid schist is an elongated mass of a soft schistose rock (No. 20) running N. 70° W. (Mag.), diagonally across the bedding; this rock was traced ten feet before disappearing under the soil; the schist is in no wise changed near the contact, and near by it is bent around some smaller lenticular masses of the same rock (No. 20).

Going north for the next half mile the following country is passed over:—

Swamp;—no exposures.

Ridge, about 200 feet above the lake, composed of black slate and fine porphyrelloid schist. On the north side of this hill gabbro, similar to that on the lake shore, was found.

Rock covered.

Very hard black slate (No. 21), containing specks of iron pyrites; also porphyrelloid schist.

Rock covered.

Black slate.

Gabbro; contact with slate not seen.

Rock covered.

Gabbro represented by No. 22.

Rock covered for 50 feet.

Black slate, No. 23; strike N. 85° E. (Mag.).

Rock covered for about 150 yards, and ground rapidly descending toward the north.

At the foot of the descent was a rather coarse porphyrelloid schist (No. 24) largely composed of a soft mineral, probably sericite.

Now comes a rather level, almost swampy, place with a few small hills; it extends for about a third of a mile, as follows:—

Rock covered; swamp, about 1,000 feet.

Black slate.

Rock covered.

Micaceous schist (No. 25); this is probably in place.

Rocks covered for about 300 feet.

One hundred feet of a heavy black hornblende schist; vertical, strike N.85° E. (Mag.). At the south side of this exposure the rock is represented by No. 26; this seems to be composed of hornblende with some feldspar; the schistose structure is very pronounced. This rock soon grades into No. 27, which is heavier and has better developed hornblende crystals; the schistose structure is not very evident, except on the weathered surfaces.

The rock was now covered for about 200 feet, and then came an exposure of a very hard, dark, fine-grained mica-schist (No. 28.). This exposure was 20 feet wide (N. and S.) and 40 feet long; strike E. and W. (Mag.); vertical.

After another swamp, 400 feet wide, came an exposure, 50 feet wide, of vertical schist; this consisted of parallel bands of several kinds represented by Nos. 29, 30, 31 and 32. No. 29 is light colored, composed mostly of feldspar, which weathers pinkish, and a small amount of mica; bands of this were of all widths up to one foot; this rock made up about one-half of the exposure. No. 30 is darker and contains much hornblende. No. 31 contains still more hornblende; bands of this and the preceding were not over six inches wide. No. 32 is a very dark, fine, mica-schist; no bands of this over two and a half inches in width were seen. Samples could be found all the way between No. 29 and No. 32, but the outlines of the different bands were very distinct. The bands would often run out to needle-points and disappear.

Beyond another swamp, about 400 feet wide, was a small hill, covered by soil, but on removing the thin layer of soil the solid rock was exposed; this rock (No. 33) is composed of hornblende and feldspar; it is quite firm and on fresh surfaces appears rather massive, but on the weathered surfaces the schistose structure is plainly seen; this schistosity is vertical and strikes N. 85° E. (Mag.). The rock contained a few small areas in which the hornblende seemed to be collected in great quantity.

Beyond the last exposure was a swamp extending northward; no hills could be seen for three-fourths of a mile.

Taking the sum of the foregoing distances, roughly estimated, we have a section, straight across the strike of the slates and schists, of 6,790 feet, or somewhat over a mile and a quarter. This would give the belt of earthy schists and slates (Kewatin) a width of 4,810 feet; and the crystalline schist belt (hornblende and mica-schists), extending north from No. 26 (No. 25 not being included, as it was not positively determined to be in place), would have a width of 1,220 feet. The width of the latter belt is probably greater than 1,220 feet, as the northern limit may not have been reached and there are 670 feet between the slates and the southern outcrop of crystalline schists where no exposures were seen.

SECTION II: This section runs directly north from the lake, and is about three-fourths of a mile west of section I, or very near the line between secs. 15 and 16, if this line were extended northward from the Minnesota side. For the first half mile from the lake there is a well-cut surveyor's line.

At the lake shore there are Animike slate fragments, and just beyond this and 15 feet above the water is a ridge of gabbro, which is about 200 feet across. A swamp extends for one-half mile from the shore; beyond this swamp is about 700 feet of dry, level ground with no rock exposures. Then comes a low ridge, 50 feet across, on which are many granite boulders and a few gabbro fragments, but no rock was seen in place. After crossing 500 feet of lower ground we came to a small ridge of gneiss (No. 34) composed of quartz and feldspar, with some hornblende and a small quantity of a light yellow mineral.

After passing over two other small ridges of gneiss there comes a range of large hills of the same gneiss; from the first appearance of this rock to the range of large hills is about 600 feet. The gneissic structure can be plainly seen on the weathered surfaces; it is vertical and runs about E. and W. (Mag.). This range is from 40 to 75 feet above the swamp, and extends eastwardly,—the southern front being precipitous and running N. 55° E. (Mag.); south of it is a valley surrounded by hills; the location is shown in Fig. 2.

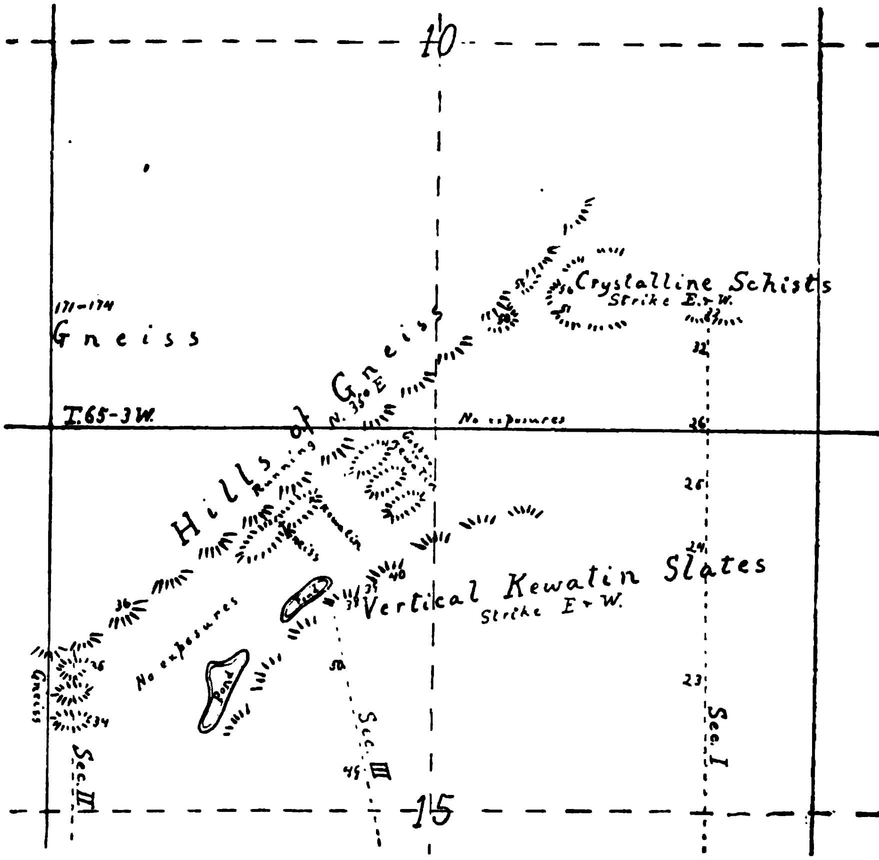

Fig. 2. Sketch showing the relation of the crystalline schists (Vermilion series) and Kewatin slates to the gneiss north of Gunflint lake.

Several pieces of micaceous schist were found in this gneiss; they were lenticular in shape and ran with the gneissic structure. The largest piece of schist was 10 feet long and 18 inches wide, and one end was irregular instead of running out to a point; No. 35 is from this piece.

A short distance east of the first observed gneiss is a trap dike, 20 feet wide, running N. 83° E. (Mag.) through the gneiss hills; this dike was traced for over 200 feet. The trap contained a few scattered crystals of feldspar, some of which are a quarter of an inch long; this rock is represented by No. 36. A mass, 3 feet in diameter, of trap quite rich in magnetite (No. 37) was found in this dike.

South of this range of gneiss hills is another range of hills made of Kewatin slates. At the place marked 38 in Fig. 2 the slates dip northward about 80°; the strike of all the slates is E. and W. (Mag.). Here the slate (No. 38) is interbedded with porphyrel (No. 39). About 100 feet east of this there is a dike of a soft schistose rock (No. 40) running parallel with the slate and porphyrel; this dike is 4 feet wide and was traced for 25 feet; it had split and inclosed a mass of the porphyrel (No. 42) which seems to have been changed by heat; the porphyrel at the contact has the same appearance as the inclosed mass. A part of the dike is much finer-grained than the rest, — this is shown by No. 41. This dike rock seems to have changed to a micaceous schist; the schistose structure runs with the length of the dike.

Extending from the slate hills to the gneiss range are three low hills composed of vertical slate, on top of which is gabbro; here the slate had been somewhat bent and broken, but the general strike was E. and W. (Mag.). Just west of these are two low hills running parallel with the gneiss range; near the eastern end of these hills is an exposure of vertical slate, striking E. and W. (Mag.); and between the two hills, and almost directly in the strike of the slate, is an exposure of gneiss. The last mentioned exposure of slate was within 100 feet of the gneiss hills. (See Fig. 2.)

Here we find a range of gneiss hills directly in the strike of the Kewatin slates; and the slate comes up to the gneiss, thus leaving no room for the belt of crystalline schists; subsequently the crystalline schists were found a short distance northeast of this place.

SECTION III: About 15° west of north, from the end of Kewatin bay (see map on page 255 of 16th An. Rep.) to the gneiss in the N. W. ¼ of sec. 15.

Forty feet from the lake is a hill, 200 feet wide, rising 40 feet above the water; the rock here is a vertical reddish-weathering schist (No. 47), striking N. 80° E. (Mag.). Six hundred feet beyond this is is another hill 300 feet wide; this is composed of vertical black flinty slate (No. 48) which weathers whitish; the strike on the south side of the hill is N. 78° E. (Mag.), and on the north side it is N. 82° E. (Mag.). After crossing a swamp we come to another hill about half a mile from the lake; here is a rather light-colored sericitic schist (No. 49) striking N. 85° E. (Mag.). About 600 feet beyond this is a large mass of gabbro (No. 50), very much decayed. And a few rods further are verti-

cal slates striking E. and W. (Mag.). This brings us to the valley shown in Fig. 2.

Crossing over to the gneiss hills on the north of this valley and following them northeast for about 1,000 feet, we come to a large hill which is 400 feet wide (N. and S.); on the western and northwestern sides of this hill are numerous outcrops of vertical crystalline schists, striking E. and W. (Mag.). The specimens collected here are No. 51 to No. 56; these were found interbedded in the same manner as described in section I. No. 51 is a hornblende schist with a large quantity of feldspar. No. 52 has more hornblende. No. 53 is a fine dark mica-schist. Nos. 54, 55, and 56 are composed mostly of hornblende which is in quite large crystals. Directly west of this hill of crystalline schists is the gneiss range, and the outcrops on the lower ridges of this range are within 150 to 200 feet of the crystalline schists. One hundred and fifty feet W. S.-W. of 51 (Fig. 2) there is an outcrop of reddish syenite (No. 57), and 40 feet north of No. 57 the syenite is represented by No. 58; No. 57 does not show any decided gneissic structure, but this structure is very evident in No. 58; it is vertical and runs N. 85° E. (Mag.); No. 58A shows this very well. Two hundred feet from the schists and directly in the strike, the gneiss (No. 59) is again seen; the gneiss of the range of hills at this place is represented by this specimen.

The range of gneiss hills here extends northeastwardly and outcrops of gneiss can be seen for a quarter of a mile in that direction. The exact contact between the schists and gneiss could not be found.

Later in the summer, while at Gunflint lake, another trip was made to the locality described above. From the last mentioned exposure of crystalline schist I followed west over the gneiss range for nearly a mile and a half; thence south half a mile, and also north for a short distance; all the rock seen (there were many exposures) was the gneiss with the gneissic structure vertical and running nearly E. and W. At only one place was there any other rock seen; this was about three-fourths of a mile west of the schists; here the gneiss held many small pieces of dark homblendic rock represented by Nos. 170, 171, and 172. No. 170 is a dark, rather fine micaceous schist. No. 171 is coarser and shows no schistose structure. No. 172 is still coarse, have large crystals of hornblende; this rock is very similar to Nos. 27, 55, and 56. All of these specimens seem to be the same as the rock composing the crystalline schists. The pieces are mostly

lenticular in shape, having the long axis east and west, but some were angular; they are collected quite thickly in a rather distinct area; on one side they disappear within ten inches, thus making a rather well defined line between the patch holding the foreign pieces and the rest of the gneiss; the other side of this patch is covered by soil, but 15 feet beyond the gneiss appears again. The rock in between the fragments contains no quartz (No. 173), but this rock gradually passes into the ordinary gneiss (No. 174) which contains large grains of quartz. This occurrence of foreign pieces in the gneiss much resembles the "conglomeritic syenite" of Saganaga lake described by Dr. Alexander Winchell in the sixteenth annual report, pages 219 and 334; also in the *American Geologist*, vol. III, No. 3, p. 153.

The facts noted in these three sections may be summarized as follows:

The crystalline schists show no evidences of having been twisted and bent,—the strike is quite constant and continues so up to within 200 feet of the gneiss; no outcrops were seen between this and the gneiss, low ground intervening. The slates in one place near the gneiss are somewhat crumpled, but this is only for a short distance and may have been caused by the gabbro which is found at that place. The crystalline schists (Vermilion series) and the slates (Kewatin) are cut across by a range of syenite gneiss hills which run N. 55° E. (Mag.). This syenite seems to be the same macroscopically as that, into which the crystalline schists pass conformably a few miles further east. The belt of crystalline schists, if continued in their strike would appear again, either on Gunflint lake north of the "narrows" or on the boundary river flowing north from the lake; but the schists are not seen here; all the rock seen for a number of miles north of the line between secs. 18 and 19, T. 65–3, along the lake and river shores (except a small area on the east side of Blackfly bay, which is Animike) is syenite, and there is no trace of the schists, unless, perhaps, it be a very few lenticular pieces of hornblende schist scattered in the syenite,—but these are found elsewhere in the syenite, far removed from any quantity of similar rock. From the facts noted it seems that the syenite has been pushed over or has flowed over the crystalline schists, or that there was a fault running N. E. and S. W. and the schist beds on the west side of this line have been pushed southwestwardly and now lie under the lake, or even further south than that. The situation of the rocks as shown by these sections is given in Fig. 2.

Iron location at Chub lake. This is in the N. E. ¼ of sec. 29, T. 65–4, and was visited in 1887 (see sixteenth annual report, pages 82 to 86). Since September, 1887, there seems to have been no working in the opening into the bluff on the north shore of the lake; No. 44 is a fair sample of the iron ore found at this place. A few rods west of this there is a steam engine and a large quantity of drill pipe. A diamond drill was worked here during the winter of 1887–8 by Mr. Millar of Grand Marais. The drill has gone down through the Pewabic quartzyte into the greenstone. A few pieces of the drill core (No. 45) were lying about; all of these seemed to be quartzyte, which in some places contained bands of a dark mineral, probably hornblende.

First falls north of Gunflint lake. These falls are in the boundary river in the N. E. ¼ of N. E. ¼ sec. 13, T. 65–4. The rock making the falls is the syenite gneiss (No. 62) of the region, with the gneissic structure running No. 80° E. (Mag.). On the Canadian side of the river is a diabase dike running N. 5° W. (Mag.); this is first seen at the waters edge on the upper (south) side of the falls. The dike rock is fairly represented by No. 61, but in some places it is finer grained, as shown by No. 61 A. After running north about 50 feet the dike suddenly ends,

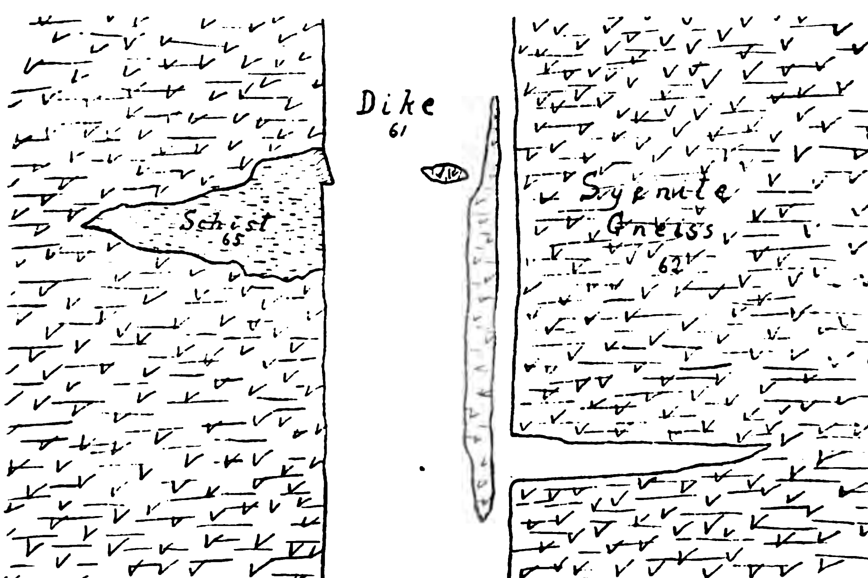

Fig. 3. Diabase dike in the syenite at the falls of the Boundary river, N. E. ¼ of N. E. ¼ sec 13, T. 65–4.

but a few feet east of this it is seen again and was traced northward for about 150 feet; here the rock contains more of a yellowish-green mineral, as is shown by No. 63; and in some places the surface is pitted (shown by No. 64) by the decay of one of the mineral constituents.

From this dike a spur, four inches wide, runs out into the syenite for four feet and ends in a point (see Fig. 3). Here is a piece of the syenite in the dike; this piece is eight feet long and four inches wide; the gneissic structure is parallel to that of the syenite through which the dike cuts. There is also a small lenticular piece of syenite in the dike, but in this the gneissic structure is at right angles to the other. A mass of hornblende schist (No. 65) is inclosed in the syenite, and one end of it is in contact with the dike, while the other end runs to a point; the schistose structure runs with the gneissic structure of the surrounding rock, but at one point (A, Fig. 3) it is slightly bent. By the firmness with which the piece of schist is connected with the syenite and by the looseness of its joint with the dike one concludes that the schist was in the syenite before the dike cut it; there is no part of the piece of schist on the other side of the dike. Several other smaller, lenticular pieces of hornblende schist, resembling the one above described and in no way connected with the dike, were found in the syenite near by.

OGISHKE-MUNCIE LAKE.

This lake lies in secs. 13, 23, 24, 26, and 27 of T. 65–6. The geology of its shores has been described in the former reports of the survey, but a few additional notes from one place are here given.

The place where these notes were taken is on the southeast shore of the lake, opposite the north end of the small island which lies just north of the narrows in sec. 24; or in the S. E. ¼ of N. E. ¼ of N. W. ¼ sec. 24. At the water's edge is a gray quartzyte (No. 76), probably the same as the gray quartzyte in the section given on page 371 of the fifteenth annual report; no bedding was seen in this quartzyte. A few feet from the shore are some vertical black slates (No. 77), striking N. 40° E. (Mag.); the contact between the slates and quartzyte was very distinct, and in one place the quartzyte extended across the strike of the slates. On the shore a few feet east of this place the quartzyte held a bed of slate about one foot wide and striking in the same direction as the other slates; on one side the slate bed by gradual

change passed into the quartzyte, while on the other side the two were separated by a sharp line. These black slates contained many siliceous bands (shown in the specimens collected) which sometimes are an inch in width. No. 78 is from one of these bands; this seems to be a gritty sandstone with some calcareous matter in it; it effervesces slightly with cold hydrochloric acid. Going from the lake these bands increase in size and frequency and the black slate gradually disappears. The rock then grades through Nos. 79, 80, and 81 to No. 82 which contains some quartz grains but is chiefly made up of calcareous or dolomitic matter. The last four specimens were taken in a distance of fifteen feet; the rock all weathered with a vertical schistose structure which ran parallel to the strike of the black slate,—i. e. N. 40° E. (Mag.). Three feet beyond No. 82 the conglomerate (No. 83) occurred; the contact between the two was covered; the conglomerate seems to contain some of the dolomitic matter. The distance from the lake shore to the conglomerate was not more than thirty feet.

BIRCH LAKE.

This lake extends through the western part of T. 61–11, and the southern part of T. 61–12. During the summer of 1886 some observations were made along the Dunka river (see the fifteenth annual report, page 340), but there was not time to visit the high ridge south of the lake in secs. 7, 8, and 9, T. 60–12, and trace it eastward to the river; consequently the writer was instructed to examine this locality. The high ridge, which is made up of syenite, was visited by Mr. H. V. Winchell, and a full account of it can be found in his report. The notes here given were taken along the trail that runs south from the lake.

The mouth of Dunka river is near the centre of sec. 33, T. 61–12; the river is canoeable for about half a mile from the mouth; at the first rapids there is a trail running south. This trail crosses the river in the S. W. ¼ of sec. 10, T. 60–12; here the river flows over gabbro (No. 117) which contains some biotite. In one small area (about ten feet square) on the surface of the gabbro there are numerous, narrow dark bands; these are brought out very plainly by unequal weathering. The bands are parallel and vertical, running N. 35° W. (Mag.). Nos. 118 and 118A show these bands; the latter specimen was taken from a loose piece. About half a mile south of this place are many gabbro fragments (No. 119) which evidently came from rock in place

near by. At the next crossing (S. W. ¼ of N. E. ¼ sec. 15) there are also some large gabbro fragments (No. 120). The river at this place flows through a swamp and no rock is exposed. Between the two crossings the trail is in many places covered with fallen trees and is difficult to follow.

Just west of the crossing in sec. 10 there is a low drift ridge; this runs a little south of west; it was followed one-fourth of a mile, where it turns more to the south and seems to disappear. A swamp extends westward from this hill, and about half a mile west of the crossing there is a low ridge, ten feet high and 300 feet long, running N. 20° E. This ridge is composed of a dark heavy quartzyte with bands of magnetite; the banding is quite regular and parallel and gives the rock a decidedly bedded appearance. The ridge runs with the strike of the quartzyte. The dip is S. 20° E. at an angle of about 30° (the direction of the dip is only estimated, as the needle was much disturbed). The specimens collected here are No. 115. This rock is probably the same as the olivinitic iron (No. 116) found on the trail in the N.W. ¼ of sec. 10 and mentioned on page 341 of the fifteenth annual report. What I have spoken of as a quartzyte is probably composed largely of olivine. The rock is a part of the Animike formation.

KAWISHIWI RIVER.

In T. 63–9. From the little bay in the S. W. ¼ of S. E. ¼ sec. 15, T. 63–9 there is a trail running northeast to the quarter post between secs. 14 and 15. On the shore the ordinary gabbro (No. 132) was found; it here held a few grains of magnetite. A quarter of a mile from the shore the trail crosses several small exposures of iron ore; these are surrounded by the gabbro; the ore is magnetite represented by No. 133, which was taken from the first of these ore exposures.

About sixty yards northwest of the quarter post between secs. 14 and 15 is a hill composed of a fine-grained rock (No. 134), which seems to be what the survey has called "muscovado." The east side of the hill is rather steep and here is some more of the magnetite (No. 135); this seems to lie under the muscovado, as it is exposed all along the base of the hill (about 250 feet) and just above and within ten feet of it the muscovado occurs in place. The contact between the two was not found. This outcrop of ore seems to be almost pure magnetite, but it occurs in

the gabbro and very probably contains quite a large per cent of titanium, as all the gabbro ores do, and so would be comparatively worthless. The ore is exposed for about 250 feet and the exposure is ten feet high; the iron seems to extend under the hill indefinitely. The specimens collected fairly represent this ore.

After reaching the quarter post between secs. 14 and 15 the trail runs north on the section line to the northwest corner of sec. 14 and then east one mile, and then north on the line between secs. 11 and 12 to Snowbank lake. There are numerous exposures of rock, but it is all the ordinary gabbro. At one place a few small pieces of magnetite were seen in the gabbro. Iron was reported just west of the quarter post between secs. 11 and 12, but after search in this locality none was discovered.

Mr. Wm. Diarmid who has a claim in the N. ½ of S. W. ¼ sec. 3, T. 63–9, says that there is an outcrop of magnetite in the gabbro near the quarter post between secs. 13 and 14, T. 63–9; also one in the S. E. ¼ of sec. 7, T. 63–8. He also mentioned outcrops of jasper in the N. E. ¼ of sec. 8, T. 63–9 and in the N. W. ¼ of sec. 4. These localities were not visited by the writer, but Mr. H. V. Winchell examined the jasper in T. 63–9 later in the season.

South of Mishiwishiwi lake. The Indians apply this name to the lake, which the survey called Bald Eagle lake in the fifteenth annual report; the lake lies mostly in secs. 25, 26, and 36 of T 62–10. A river flows into the southeastern corner of the lake, and about a mile from the mouth of the river, or in the N. W. ¼ of sec. 5, T. 61–9, there is a stream flowing into the river from the south; this stream is canoeable for about a mile and a half. On the right bank of the stream and an eighth of a mile south of its mouth is a hill of gabbro, which appears to be the west end of a low ridge running east and west. This gabbro (No. 136) has a gneissic structure, which is vertical and runs N. 15° W. (Mag.), making the rock break more readily in this direction than in any other. In some places the gabbro lies in horizontal beds from two to four inches thick. The rock seems to be almost entirely composed of a feldspar (probably labradorite) and a mineral which is probably olivine; this, when not decayed, is of a yellowish-green color, but its hardness is below 6. A few rods further south, on the left bank of the stream is a small hill of the some gabbro showing the gneissic structure running in the same direction,—i. e. N. 15° W. (Mag.).

About a third of a mile south of the last mentioned hill is another gabbro hill on the left bank of the stream. The rock here is similar in composition to that above described, but is coarser grained and does not have the gneissic structure seen in the other; but many of the weathered surfaces have a peculiar banding, which is caused by the feldspar crystals being aggregated in certain lines that are vertical and run N. 10° W. (Mag.). No. 138 is a fair sample of the gabbro from this locality, while No. 137 shows the banding. The olivine, as it decays, loses its yellowish-green color and becomes darker (sometimes having a deep red color, like garnet) until on the weathered surface of the rock it appears as rusty spots. The decay of the olivine causes the rock to crumble and be easily shattered. From this hill a higher range, running east and west, could be seen about ten miles to the south.

A mile and a half from its mouth the stream narrows and rapids soon occur; here is a poor, not recently used, portage on the left side of the stream; beyond this portage the stream is crossed by many fallen logs, so we went no further.

About a mile and a half south of this place the low rounded hills, a form common to a gabbro country, seem to be collected into a low range that runs east and west. The country south of Mishiwishiwi lake has been burnt and is now partially covered by small poplars and birches, although many of the hills are treeless.

The small lake in sec. 32, *T.* 63–10. A small island near the southern shore of this lake is composed of a red syenitic gneiss (No. 139), the gneissic structure being very easily seen on the weathered surfaces and running N. 50° E. (Mag.). A little north of this is another island composed of about the same syenite, but this (No. 140) does not show the gneissic structure. These islands are in the N. E. ¼ of S. W. ¼ sec. 32. On the west side of the little bay, which is in the N. W. ¼ of N. W. ¼ sec. 32, the syenite is lighter colored and has large crystals of hornblende as shown by No. 141. At the portage, in the N. E. ¼ of N. E. ¼ sec. 31 there is a light gray gneiss (No. 142) with the gneissic structure running N. 60° E. (Mag.); this gneiss holds pieces of a darker rock (No. 143), and seems to be mixed in with a mica schist and a hornblende schist a few feet south of the portage. On a little point, near where the line between secs. 31 and 32 crosses the southern shore of the lake, there is red syenite like No. 139. There was not time to examine the

whole lake, but the shores seemed to be made up of syenite, of which No. 140 is a fair sample.

Mr. H. V. Winchell found the rock on the southern (?) shore of this lake to be a dark hornblende rock (No. 144), which grades into the ordinary syenite through No. 145 and No. 146.

LAKE ISABELLE.*

This lake lies in secs. 25, 35, and 36 of T. 62–8 and secs. 30 and 31 of T. 62–7.

On the west shore of the little bay in the S. W. ¼ of N. W. ¼ of sec. 35, the gabbro is composed principally of labradorite with a small amount of a glassy yellow mineral (probably olivine) and magnetite, which seems to cause the rusty spots near the surface of the rock; a few scales of biotite are also present; this gabbro is represented by No. 147. A few rods further north there is an irregular vein of granulyte (No. 148) in the gabbro; the vein is eight inches wide; one of the specimens collected shows both the vein rock and the gabbro; in the vein rock there are a few scattered scales of biotite.

On the west side of the larger bay, which is in the N. W. ¼ of sec. 35, there is a perpendicular cliff (5 to 15 feet high) of gabbro (No. 149) that is coarser grained and contains considerable olivine, but some of this yellow color may be due to a decayed condition of the labradorite. At the head of this bay, gabbro similar to No. 149 occurs.

On the shore in the S. W ¼ of N. E. ¼ sec. 35 there is a dark, heavy, fine-grained trap rock (No. 150) which gives a metallic ring when struck by the hammer; this grades into No. 151 which is coarser. A few rods back from the shore Nos. 152 and 153 were found in low outcrops; these seem to be but different conditions of No. 150. No. 152 contains considerable magnetite. A little further north on the shore this rock contains small patches of biotite, as shown by Nos. 154 and 155, the latter being a decayed condition of the former. These grade into No. 156 which is coarser. On the shore, a few steps north of No. 156, this rock (trap) is found in contact with the gabbro (N. ½ of N. E. ¼ sec. 35); the line of contact was not always distinct and in some places, as near as could be determined from the smooth-weathered surface, the transition from one rock to the other occupied two

*Only the north shore of this lake is here described; for the description of the rest of the lake, and also of most of the country between here and lake Superior (this lake and the two following being the only ones here mentioned), consult the report of Mr. H. V. Winchell.

or three inches. No. 157 represents the trap near the contact with the gabbro.

The rest of the north shore of the lake has many gabbro outcrops; for long distances there are smooth, flat exposures of gabbro rising but a few inches above the water and extending back for several yards from the shore. Three dikes are found cutting the gabbro. The first is in the N. E. ¼ of N. E. ¼ sec. 35; this dike is twenty inches wide and was traced for over sixty feet; it runs N. 30° W. (Mag.); the rock is a very fine diabase (No. 158); the contact with the gabbro is distinct. This dike occurs only a few rods north of the contact mentioned, about ten lines above. The second dike is in the S. W. ¼ of sec. 30, T. 62–7, is twenty feet wide, and could be traced only twenty-five feet, as the water covered it on one end and the soil on the other; the rock is diabase and is represented by No. 159, which was taken from the centre of the dike, and by No. 160, which was taken from one side (only one side of the dike was finely crystalline); No. 160 appears to be the same as No. 158; the contact is distinct. The third dike is in the W. ½ of sec. 31, T. 62–7 and is composed of a fine diabase represented by No. 161; this dike is fourteen inches wide and can be traced only a few feet.

BELLISSIMA LAKE.

This lake lies in the southeastern corner of T. 61–7. The north shore was examined by the writer. The shore is usually lined with boulders, most of which are large gabbro boulders, the others are smaller and apparently come from the drift; some of the latter are probably from Cupriferous rocks. Wherever the rock was exposed it was found to be very coarse labradorite gabbro, as shown by No. 162, which was obtained on the shore, about half a mile east of the west end of the lake. The north shore was low and there were no hills near the lake. No glacial striæ were seen.

PINE LAKE.

This lake lies in the S. W. ¼ of sec. 21 and in the N. W. ¼ of sec. 28, T. 60–6.

On the north shore, about one-fourth mile east of the portage from lake Harriet (just west of Pine lake), is a low rock outcrop at the water's edge; this outcrop is about twenty feet square. The rock is of three kinds; (1) a gray rock (No. 163) composed

mainly of a gray feldspar; (2) a red rock (No. 164) made up of quartz and red feldspar; (3) a very fine dark trap (No. 165) holding crystals of red feldspar. No. 164A shows a darker and more siliceous condition of No. 164. Nos. 164 and 165 are very much mixed, each containing pieces of the other (see Nos. 164, 165, 165 A, and 165B). No. 163 is not found mixed with the others, but it contains a few small pieces of a dark siliceous rock as shown by No. 163A. No. 163B is intermediate between No. 163 and No. 164. The dark trap much resembles some of the trap of the Cupriferous; it is split by numerous parallel planes that are vertical and run N. 5° W. (Mag.); these are shown by the specimens.

A diabasic rock (No. 166) outcrops on the east shore near the southern end of the lake; it holds a few scattering crystals of feldspar which are sometimes nearly an inch long. This outcrop and the one mentioned above are the only two outcrops on the north and east shores of the lake.

Mr. H. V. Winchell reports several outcrops of fine diabase on the west shore of the lake; Nos. 167. 168, and 169 represent this; they seem to differ only in fineness, and all of them are much finer than that from the east shore.

The notes from Mayhew to Flying Cloud lake (inclusive) were taken on a trip from Gunflint lake south to Brulé lake and then north and west through townships 63–4, 64–4, 65–4, 65–5, and 65–6 to Ogishke-Muncie lake. The object of this trip was to examine reported iron ore locations, most of which were not found as reported,—there usually being no ore to be seen. The country passed over is one not usually traveled by white men and is seldom used by Indians except in winter; consequently the portages are very poor and badly cut, it oftentimes being necessary to go ahead and recut a portage before the canoe could be taken across. This fact, together with the fact that the township plats were very inaccurate, caused much unavoidable delay and waste of time. There are, however, some fair portages; those from Gaskanas lake to Brulé lake are quite good, and the portages from lake Ida Belle north to the lake in the S. W. ¼ of sec. 35, T. 65–4 are wide and well cut out, being used as winter roads by the Indians.

Several of the lakes on this trip were given names, as they have none on the township plats nor on any of the maps accessible. It must be admitted that this is rather a bad principle to follow, the right way being to give them the names by which

they are known to the native Indians or, better still, to give the English equivalents of the Indian names; but, as the Indian names were not obtained, it was thought best to have some name by which each lake could be known. The lakes thus named are Straight, Meed's, Stray, Sham, Lost, Georgia, Surveyor's, Found, Ida Belle, Narrow, Round, and Draper lakes.

MAYHEW LAKE.

Mayhew lake is a narrow strip of water, about one-fourth of a mile wide and a mile long, extending east and west through the south half of sec. 36, T. 65–3. It is 305 feet above Gunflint lake. A rough, steep portage runs from Loon lake to Mayhew lake.

The ordinary labradorite gabbro (No. 175) is seen on the south shore in S. W. ¼ of S. E. ¼ sec. 36. On the end of the little point, which is in the S. E. ¼ of S. E. ¼ sec. 36, the gabbro (No. 176) has changed somewhat, and on the south side of this point it surrounds a large mass of iron ore. This ore (No. 177) seems to be principally magnetite, with a little scattering feldspar, but, as it is in the gabbro, it very probably contains a considerable amount of titanium. The exposure of ore was 30 feet wide and extended for about 300 feet along the shore, rising 15 feet above the water. The contact between the ore and gabbro was found at one place; here the gabbro does not pass into the iron ore by gradually acquiring more magnetite, but there is a sharp and distinct line between the two.

There is a trail, on the town line, running south from the lake; this trail was followed nearly three-quarters of a mile, and several gabbro ridges, running east and west, were crossed; the gabbro is much decayed and is nearly half made up of magnetite (No. 178). From the town corner (T. 65–2, 65–3, 64–2, and 64–3) a trail runs west along the line between townships 64 and 63. About a quarter of a mile west of the corner, and just south of the line, there is a small lake; here were seen many fresh beaver gnawings. Gabbro was the only rock seen on this trail (it was followed no further than the small lake mentioned above).

IRON LAKE.

This lake is a narrow body of water extending through the south half of secs. 31, 32, and 33 of T. 65–2. It is the same hight as Mayhew lake, and the two are connected by a narrow strip of water, 60 or more feet in width.

The point, which is crossed by the line between secs. 31 and 32, also the north shore of the lake in the south half of sec. 32, were examined in order to see the iron ore at these places. (This lake was described in the tenth annual report, page 80.) The point was crossed twice west of the section line and once east of it, but no ore was found except a seam of magnetite (containing a little feldspar) eight inches wide and twelve feet long, and a few small masses (No. 179) of the same in the gabbro. A low ridge of gabbro runs along the southern shore of this point, and in this ridge the magnetite was found. The gabbro is, in places, quite rich in magnetite; this is shown by No. 180, which was taken near the section line. Four sections of a quarter of a mile each were made north of the lake in sec. 32, but no ore was found. The rock was all gabbro, and none of it contained as much iron as No. 180. The shores of Iron lake are usually lined with gabbro.

PORTAGE LAKE.

Portage lake is mostly in the north half of sec. 4, T. 64–2, but an arm extends east for half a mile in sec. 5, and the line between T. 64 and 65 crosses the northern part of the lake, making a small portion of it in sec. 33, T. 65–2. It is 25 feet above Iron and Mayhew lakes.

In the S. E. ¼ of N. W. ¼ sec. 4, on the shore, is an exposure of a fine "muscovado" (No. 181); one of the specimens collected shows a porphyritic crystal which is probably labradorite. The relation of this rock to the gabbro could not be found at this place. On the south shore, in the N. E. ¼ of N. E. ¼ sec. 4, there is an exposure where the gabbro and "muscovado" were found together. The former held several large masses of the latter rock that looked like dikes, but they could not be traced far enough to determine that they were dikes. There was one lenticular piece of "muscovado" (15 inches long) in the gabbro, and in places the gabbro held pieces of the other rocks in which were small bits of the gabbro. The bottom of the exposure was entirely of gabbro. It could not be positively ascertained which was the older of the two rocks, but the "muscovado" seems to have broken up through the gabbro.

On the south shore, in the N. W. ¼ of N. W. ¼ sec. 3, the gabbro is in distinct beds from two to eight inches thick and dipping south about 30°. This bedded structure, dipping in the same direction and at about the same angle, was noticed

several times, but at no other place were the beds as thin and as distinct as here. The gabbro was seen at several other places on the south shore of the lake.

POPLAR LAKE.

This lake lies mostly in secs. 1 and 12 of T. 64–2 and secs. 7 and 8 of T. 64–1; a small portion is in sec. 6, T. 64–1, and a narrow bay extends into the S. E. ¼ of sec. 2, T. 64–2. It is 20 feet below Portage lake. A portage leads from the east arm of Portage lake to the extreme northwestern point of Poplar lake; the trail is rather plain at the western end, but at the other end there is almost no trail at all. No one seems to have been over the portage for two or three years. No portage could be found leading to Duck lake (a small lake in the eastern part of sec. 3, T. 64–2) mentioned by N. H. Winchell in the tenth annual report, page 79.

Gabbro was seen in several places on the portage from Portage lake. On the little point in the N. W. ¼ of N. E. ¼ of N. W. ¼ sec. 12, T. 64–2, the gabbro is finer than is usually found. At this place it varied from No. 182 to No. 183; the former shows a gneissic arrangement of the minerals, but this is not constant. On the shore in the S. E. ¼ of N. E. ¼ sec. 12 the gabbro (No. 184) has the labradorite collected together in spots, but this soon grades into the ordinary gabbro.

STRAIGHT LAKE.

This is a small, narrow lake, half a mile long and 100 yards wide, extending northwest and south east in the S. W. ¼ of sec. 7, and the N. W. ¼ of sec. 18, T. 64–1. It is 25 feet below Poplar lake and is not shown on the township plat. The portage starts from Poplar lake on the range line and runs a little east of south; it is about one-fourth mile long. Gabbro was seen on the portage.

CARIBOU LAKE.

Caribou lake is in sec. 18, T. 64–1 and sec. 13, T. 64–2. It is ten feet below Straight lake. The portage from the latter lake is a quarter of a mile long. Gabbro occurs on Caribou lake at the portage and was also noticed in several places along the north shore. There is a claim cabin in the S. W. ¼ of N. E. ¼ sec. 13, T. 64–2, probably built within the last year, and from this cabin

a line ran north for one-fourth mile; no rock was found except some gabbro at the north end of this line. The south and west shores and some of the islands of this lake have not been burnt, but all the country passed through since leaving Loon lake was burnt a number of years ago and is now covered with a not very dense growth of poplars and birches, usually not more than 25 feet high.

MEED'S LAKE.

Meed's lake is less than half a mile wide, and extends through the northern part of secs. 14 and 15 into secs. 13 and 16 of T. 64–2. It is 10 feet above Caribou lake. The timber along the shores is very dense, composed mostly of spruce, and extends down to the water's edge. No portage could be found from Caribou lake to this lake, so it was necessary to portage up the creek bed (S. E. ¼ of N. W. ¼ sec. 13, T. 64–2) for 100 yards, where the creek widens into a pond, and from the west end of this pond 200 yards more to Meed's lake. There is no high land to be seen from this lake except a hill, 90 feet above the water, in the N. E. ¼ of N. W. ¼ sec. 15.

On the geological map in the fifteenth annual report iron ore is marked all along the north shore of this lake, but, after careful search, none was found. The north shore of the lake was examined and no rock was seen except several outcrops of gabbro. Several trips were made north from the shore, as follows: (1) One-fourth mile north, a little west of the centre of sec. 15; a hill of gabbro (No. 185), mentioned above, was the only rock found. (2) Mr. Meeds went more than half a mile north about one-fourth mile west of the line between secs. 14 and 15; he reported several outcrops of gabbro. (3) One-half mile north from the little bay which extends into the S. W. ¼ of S. W. ¼ sec. 11; no rock found in place except a little gabbro at the shore. (4) From the east side of this little bay where the line between secs. 11 and 14 crosses the shore, northeast one-third mile, and then south to the lake shore. Several low ridges of gabbro, running east and west, were crossed. On the way south to the lake a small exposure of almost flat-lying (dipping S. 4°), bedded rock was found. This exposure was not more than six feet across; the rock is similar to some of the Animike beds of Gunflint lake and vicinity. One specimen (No. 186) was collected; this has a structure somewhat resembling öolite; pieces of this are quite common on the beaches of Gunflint lake. The rock is undoubt-

edly Animike, but I was unable to determine whether it was in place. Search was made for more of this rock, but none was found.

NORTH BRULÉ LAKE.

There is a portage starting from Caribou lake a little west of the line between ranges 1 and 2 and running south a quarter of a mile to the northwestern arm of North Brulé lake. North Brulé lake is a very irregular body of water lying in secs. 19, 20 and 29 of T. 64–1 and sec. 24 of T. 64–2. It is 20 feet below Caribou lake. Only that part of the northwestern arm lying in the N. E. ¼ of sec. 24, T. 64–2, was examined; here gabbro was seen in two outcrops. The shore has not been burnt and is covered mostly by spruce and cedar.

STRAY LAKE.

This lake is long and narrow; it lies in the north half of sec. 24, T. 64–2 and extends nearly half a mile into sec. 23. It is 30 feet above North Brulé lake. The portage leading from the last lake to Stray lake starts almost directly south of the one from Caribou lake. Gabbro was seen on this portage and also along the stream that flows from Stray lake to North Brulé lake.

GASKANAS LAKE.*

This lake is nearly three miles long, and not more than half a mile in width. It lies in secs. 22, 23, 24, 25, 26, and 27 of T. 64–2, and is 15 feet above Stray lake. We could find no portage leading south from Stray lake and so cut one to the pond which is in the S. W. ¼ of sec. 24. From this pond an old and poorly-cut portage leads to Gaskanas lake. Gabbro was seen at each end of the last portage, also on the east side of the little bay in the S. E. ¼ of N. W. ¼ sec. 26. This lake is a very pretty little sheet of water and is dotted with many green islands. The shores are densely wooded and along the south shore, especially in sec. 26 where there are two claim cabins, there is considerable good white pine.

*This name is taken from Heinze Bros.' "Map of the Vermilion Iron Range." This map gives Winchell lake as Ababikaigan lake.

WINCHELL LAKE.*

Winchell lake is a long, narrow body of water, over five miles in length and less than half a mile in width, extending east and west in the southern part of T. 64–2 and running half a mile into T. 64–3. It is 30 feet above Gaskanas lake. The portage from Gaskanas lake (this starts from the bay in S. E. ¼ of N. W. ¼ sec. 26) is very good,—the first good one seen since leaving Gunflint lake. The water of Winchell lake is deep and very clear; the shores are well covered with timber which is composed mostly of spruce and birch with some scattering white pine. The Grand Marais Indians call this Mountain lake, probably because of the high ridge that extends along the south shore.

Gabbro occurs in place at the portage in the N. E. ¼ of S. W ¼ sec. 26, T. 64–2, and there are outcrops of rock (apparently gabbro) all along the north shore, but only one of these was visited; here (S. E. ¼ of S. E. ¼ sec. 29) the gabbro (No. 187) is like the ordinary labradorite gabbro found further north, but is a little finer. We followed along the south shore of the lake, but no rock outcrops were seen until we came to the point which is crossed by the line between secs. 31 and 32, T. 64–2; here a high ridge, which extends all along the south shore of the lake and rises 50 to 100 feet above the water, comes to the shore and forms a precipitous cliff nearly 100 feet high. This cliff is composed of gabbro (No. 188) which differs from the ordinary gabbro in that it contains a considerable amount of a whitish feldspar mixed with the labradorite. The gabbro extends along the shore for a quarter of a mile west of this point.

In the N. W. ¼ of N. W. ¼ sec. 31, T. 64–2, the above mentioned ridge is cut by a small stream flowing from Sham lake, which is just south of Winchell lake. Just east of this stream is a bluff rising 80 feet above the water. The rock at the foot of the bluff is covered by large angular masses of rock that have fallen down from higher up. The first rock seen *in situ* is almost 20 feet above the water level; it is gabbro (No. 189) that is like the ordinary labradorite gabbro, except that it is more compact and contains a little light-colored feldspar. Twenty feet higher up the gabbro is represented by No. 190; this is similar to No. 189, but has more of the light-colored (pinkish) feldspar. This feldspar increased until, ten feet above No. 190, the rock was

* This name is taken from Reisenegger's map of Northeastern Minnesota.

largely composed of it. This rock (No. 191) has a red color and seems to be the gabbro changed by heat; this could not have been done by forest fires as none have passed over the shore. The feldspar crystals vary all the way from the dark (almost black) labradorite through white to a decided red. This rock is about as coarse and, with the exception of color, has the same appearance as the ordinary gabbro. None of the specimens above mentioned contain any quartz. Two feet above No. 191 the rock is very dark and tough, being composed mostly of a black mineral probably hornblende, which is not always in definite crystals; this gives the rock (Nos. 192 and 193) the appearance of having a dark compact ground mass in which are scattered blotches of pinkish feldspar; in these feldspar blotches there are numerous small quartz grains. A little higher up occurred a fine pinkish gray syenite (No. 194). No. 195 was taken just above this and No. 196 from the top of the bluff. The latter is coarser and is a distinct syenite. On examining the bluff at another place the syenite was found at the top and the gabbro near the bottom. Among the angular pieces at the foot of the bluff one (No. 197) was found which seems to be intermediate between the highest gabbro (No. 191) and the syenite; it resembles No. 191 and, like it, has labradorite (?) crystals, but it also contains numerous quartz grains while No. 191 has none. On the north end of the portage to Sham lake the rock is a condition of the gabbro,— No. 198.

The above mentioned bluff shows an apparent transition from the gabbro at the bottom (No. 189) to the syenite at the top (No. 196), *the syenite lying on the gabbro*. The change is gradual, and rapid at only one place — between No. 191 and No. 192; here the transition occurs within two feet; the quartz in No. 192 is in such small grains that it was not noticed in the field, so the exact place where the quartz first appears was not determined; however, there is no distinct contact line between these two rocks, but the change from one to the other is quite sudden. It seems that the syenite is of igneous origin and has flowed out over the gabbro, the gabbro being changed somewhat by molten rock above it. No. 191 represents the changed state of the gabbro and No. 192 is the first, or lowest, part of the syenite; at any rate the change occurs between these two,— the distinct labradorite crystals disappearing and the quartz coming in.

SHAM LAKE.

This is a small lake, less than a mile long, on the line between sec. 31, T. 64-2 and sec. 36, T. 64-3. It is 15 feet above Winchell lake and is connected with it by a small stream which is a short distance east of the range line. The portage between the two lakes is less than one-eighth of a mile in length. Sham lake has no long arm extending west through sec. 36, as is shown on the township plat.

The rock at the south end of the portage is represented by No. 199; this is similar to No. 192 except that the hornblende is in distinct crystals and the quartz is not very plentiful. On the east side of the lake, in the S. W. ¼ of N. W. ¼ sec. 31, a fine red syenite (No. 200) occurs; it is composed of a red feldspar and hornblende, the feldspar making up about two-thirds of the rock; no quartz can be seen with a hand lens, but it probably contains some. The rock is probably the same as the fine red syenite or "red rock" found by Prof. N. H. Winchell both east and west of this place. Near the southwest corner of the lake, in S. E. ¼ of S. E. ¼ sec. 36, there is a low outcrop of a rock (No. 201), apparently part of the transition from gabbro to syenite; it resembles Nos. 192 and 193 from Winchell lake.

LOST LAKE.

From the south end of Sham lake there is a portage running S. S. W. for about a mile to Lost lake. This lake is not given on the township plat, and as near as could be determined it lies in the S. ½ of sec. 1 and the N. ½ of sec. 12, T. 63-3. It is about half a mile long (N. and S.) and a quarter of a mile wide. The shores are well wooded and have considerable good white pine. This lake is 30 feet above Sham lake.

On the portage from Sham lake the fine red syenite, same as No. 200, occurs in several places just east of the trail. On the west side of the lake, in S. E. ¼ of S. W. ¼ sec. 1, there is a high bluff of this same syenite; and many angular pieces have fallen down making a large talus; at this place the rock is represented by No. 202, which is of a brick-red color and contains even less hornblende than No. 200.

BRULÉ LAKE.

From Lost lake there is a portage of a quarter of a mile running S. S.-W. to a small lake, not shown on the township plat,

in the W. ½ of sec. 12, T. 63–3. This small lake is about a quarter of a mile in length. From its southern end a portage of less than a quarter of a mile leads to the bay of Brulé lake that extends into the S. W. ¼ of sec. 12, T. 63–3.

Brulé lake is the largest lake seen since leaving Gunflint lake, —in fact it is the largest lake in Minnesota south of the boundary and east of range 9. It is seven miles long, the average width being a mile, and extends through the central part of T. 63–3 and a mile and a half into the western part of T. 63–2 (that portion of the lake in this township was not visited). The north and west shores have not been burnt; here is some good white pine. The southern shore was burnt some years ago and is now covered with a second growth of birches. There is a claim cabin on the point in the N. E. ¼ of N. W. ¼ sec. 13, and from a Grand Marais Indian, we learned that there were several more about the lake. Brulé lake is 75 feet below Lost lake. The water is cle and deep.

In the S. E. ¼ of S. W. ¼ sec. 12, at the water's edge, there is a low exposure of a dark siliceous trap rock (No. 203), which appears to be perfectly homogeneous under the hand lens. This rock contains a few small crystals of iron pyrites. No bedding structure could be seen but there were many small joints cutting the rock; in one place these were parallel and dipped south about 20°. A little further south along the east shore of this bay (the bay in the S. W. ¼ of sec. 12) is an outcrop of a rock (No. 204) composed almost entirely of plagioclase feldspar crystals of all sizes up to half an inch in length; these crystals seem to be imbedded in a dark, finely crystalline matrix, but this is a very small part of the rock.

On the point in the S. E. ¼ of N. E. ¼ of N. W. ¼ sec. 13 the rock at the water's edge is a white feldspar porphyry (No. 205); the feldspar crystals run up to those an inch in length; the matrix is dark and finely crystalline; it makes up about one-half of the rock. No. 204 is probably a condition of this porphyry. Ten feet above No. 205 and 30 feet back from the shore there is another feldspar porphyry (No. 206); this seems to be different from No. 205, as the matrix is much finer, darker and apparently more siliceous, and the feldspar crystals, instead of being white, are of a dull reddish-brown color; the matrix comprises about three-fourths of the rock; the feldspar crystals weather white. The rock between these two porphyries is covered by soil.

A few yards south of No. 206 is a small exposure of a brick-red rock (No. 207) which is composed of a reddish, homogeneous and siliceous ground-mass, in which are small crystals of a brick-red feldspar, a dark mineral (probably hornblende) and quartz. This rock might be called a quartz porphyry and is entirely different from any of the others on this point. It is cut by many parallel planes (shown in the specimen) which are vertical and run east and west. On the north side of this exposure the red rock is in contact with a fine diabase (No. 208); the contact line is distinct but was exposed for only a few inches; where seen it was vertical and ran east and west. Near the contact the ground-mass of No. 207 becomes darker and more siliceous; this is shown by No. 207A.

Where the line between secs. 13 and 14 strikes the north shore the rock is similar to No. 204. This same rock occurs on the point in the N. W. ¼ of N. E. ¼ sec. 14 and also on the small island just south of this point. The shore was not examined again until reaching the large island in the centre of sec. 17; no outcrops were seen along the south shore of this island. On a small island in the S. E. ¼ of S. E. ¼ sec. 18 there is a dark, diabase-like rock inclined to be amygdaloidal (No. 209); this is quite finely crystalline and inclines to a dark purple color. In places in this rock there are small blotches of a reddish feldspar; the centre of each blotch is composed of a dark mineral, probably hornblende. This rock also occurs near the west end of the island that is cut by the line between secs. 17 and 18, and on the east end of the portage towards Georgia lake.

It is to be regretted that we were unable to more carefully examine the relations of the rocks from the south shore of Winchell lake, to and through Brulé lake, but our provisions would not warrant a longer stay.

LAKE GEORGIA.

This lake lies in the W. ½ of sec. 18, T. 63–3, and sec. 13, T. 63–4, and small bays run into secs. 14 and 24. It is 6 feet below Brulé lake. The shores have been burnt and are now covered with small birches and poplars. A stream flows from Brulé lake to lake Georgia and the portage between the two lakes is in the S. W. ¼ of sec. 18; it is only 200 feet, and not a quarter of a mile, as shown on the plat. Lake Georgia has no arm extending into sec. 12, T. 63–4, as is shown on the government plat.

In the north branch of the arm that extends into the S. W. ¼ of sec. 18, a short distance west of the portage from Brule lake, there is a rock (No. 210) which appears to be a condition of the gabbro. A little west of this, and on the north shore of this arm, is an outcrop of a feldspar porphyry (No. 211); this seems to be somewhat similar to No. 206; the feldspar crystals are reddish, but rather scattered — probably making up not more than one-tenth of the rock. On the north shore of the lake in the N. E. ¼ of S. W. ¼ sec. 13, T. 63–4, there is a trap rock (No. 212); which is in contact with the gabbro, here represented by No. 213; the two specimens were taken within three feet of each other; the contact line was covered by soil. No. 212A shows the trap further from the contact; it is much coarser than No. 212. Gabbro also occurs where the line between secs. 13 and 14, T. 63–4 touches the northern shore of the lake.

SURVEYOR'S LAKE.

This lake is in sec. 12, T. 63–4. It is shown on the township plat as an arm of lake Georgia, but there is no connection between the two except a small stream flowing from Surveyor's lake; the portage between these lakes is in the N. E. ¼ of sec. 13 and is over an eighth of a mile long. The aneroid shows no difference in hight between the two lakes, but Surveyor's lake is a little higher than the other. North and east of this lake are hills 50 to 100 feet high.

In the S. W. ¼ of sec. 12 there is a deep bay running west for nearly half a mile. At the end of this bay on the portage going west to Found lake is a fine red syenite (No. 214), similar to Nos. 200 and 202. There is a ridge extending along the north side of this bay; the red rock (syenite) in the ridge can be seen from the lake.

FOUND LAKE.

Found lake is in the S. ½ of sec. 11, T. 63–4. It is a small lake, less than half a mile long (east and west) and is not shown on the township plat. The shores have been burnt and are now covered with a second growth of birch and poplar. This lake is the same hight as Surveyor's lake.

The fine red syenite, similiar to No. 214, occurs in several places on the portage from Surveyor's lake. On the north side of the lake is a hill, 50 feet above the water, composed of a dia-

base (No. 215). On each side of this hill the red syenite occurs, thus making it seem as if the diabase had cut through the syenite; the two rocks were not seen in contact. The north shore of the lake is mostly made up of the fine red syenite. In one place this syenite held angular pieces (none were seen over three inches in diameter) of a fine dark rock; this is shown by No. 216, which shows both the dark rock and the syenite. In this specimen the syenite is easily seen to contain much quartz;— in the other specimens of this syenite (Nos. 200, 202, and 212) quartz can not be clearly seen with the hand lens.

LAKE IDA BELLE.

This lake is very irregular. It lies in secs. 1, 2, 3, 10, 11, and 12 of T. 63–4, while bays extend a short distance into T. 64–4, T. 64–2, and T. 63–3. It is 30 feet below Found lake. The country around lake Ida Belle, except a small portion at the northeast corner of the lake, has been burnt, and there are vast exposures of rock all around the lake not yet covered by a second growth of trees.

This lake lies in the great gabbro sheet; probably nine-tenths of the rock around the lake is gabbro, the rest being trap and fine red syenite. A belt of iron ore was reported running from sec. 1 to sec. 18, T. 63–4; the entire lake shore was examined, also part of the country southwest of the lake, but no iron ore was found;—in fact the only iron seen consisted of a few bands or seams of magnetite in the gabbro. Fresh beaver cuttings were seen along the shore in sec. 10, T. 63–4. No portage could be found from the last lake to lake Ida Belle, and so one was cut straight north for about one-third of a mile; this brought us to lake Ida Belle near the centre of Sec. 11, T. 63–4.

In the S. W. ¼ of N. E. ¼ sec. 11, T. 63–4, the gabbro (No. 217) occurs and continues along the south shore most of the way to the stream that enters the lake in the S. E. ¼ of sec. 10. In the S. W. ¼ of N. W. ¼ sec. 11, just east of the line between secs. 10 and 11, there is an exposure of diabase (No. 218). The gabbro on the little point in the S. E. ¼ of sec. 10 is cut by a dike of fine diabase (No. 219); the dike runs a little west of north; it is three feet wide and was traced twenty feet. The gabbro at this point is represented by No. 220, which is exactly similar to that found much farther north.

A trip was made south to the corner between secs. 10, 11, 14, and 15 and then west along the line between secs. 14 and 15 for

nearly half a mile; the line could be followed no farther, and so we went as near west as possible until two miles west of the above corner. Many rounded hills of gabbro were crossed,—in fact all the rock seen was gabbro except a small outcrop about three-fourths of a mile from the corner; this outcrop consisted of a fine-grained rock (No. 221) which, if it were a little more decayed, would resemble what has been termed "muscovado." One of the specimens collected (No. 222) is from a vein which contained large crystals of hornblende, an inch or more long. In some places there were small patches or seams of gabbro that contained considerable magnetite, as shown by No. 223, but in no place did the magnetite make up more than one-third of the rock. At one place, one and a half miles west of the corner, there was a thin scale, not much more than half an inch thick, of magnetite lying on the gabbro; this extended only about 20 feet; No. 224 is from this scale of magnetite. From the last place (one and a half miles west from the corner) Mr. Meeds went north for half a mile, and found nothing but gabbro. A section was also made south for half a mile; the gabbro was the only rock seen.

Gabbro continues along the north and west shores of the lake in sec. 10; it was examined in several places. There is a very small bay in the N. W. ¼ of N. E. ¼ sec. 10; on the east side of the entrance to this bay there is an exposure of gabbro sloping down to the water. The surface of the gabbro is spotted with small and irregular pieces of the fine red syenite (No. 225), and there are veins of this syenite in the gabbro; there is also a large piece of syenite, 10 by 20 feet. This large piece and the smaller pieces of syenite seem to lie on the gabbro; and this, together with the fact that the gabbro is cut by veins or dikes of the syenite, would indicate that *the syenite is of later date than the gabbro.* The top of the gabbro exposure is cut by an irregular dike, which at one end is three feet wide; it then widens out to twelve feet. The direction of the dike is nearly east and west, and it was traced forty feet. The syenite at this place is represented by No. 225, the dike rocks by No. 226, and the gabbro by No. 227. This is the first place that the writer has found the fine red syenite in contact with the gabbro. The two are seen in contact again at the northwest corner of this little bay; here the contact is vertical, and is a sharply defined line, but there is only a small (four feet wide) strip of syenite exposed.

Many outcrops of gabbro are seen along the west shore of the lake till we reach a small island in the N. E. ¼ of S. E. ¼ sec. 3. On the north side of this island the gabbro and the fine red syenite are again seen in contact; *here the gabbro lies on the syenite*, which is represented by No. 228. A bluff of rock about thirty

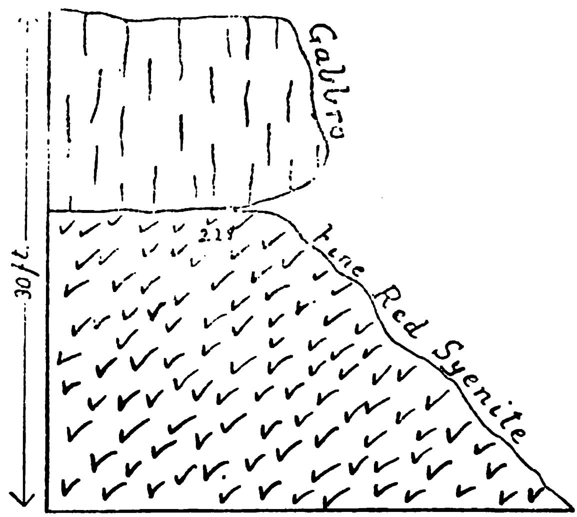

Fig. 4. Gabbro lying on fine red syenite, lake Ida Belle.

feet high is exposed; the upper part is composed of gabbro, which projects out beyond the syenite lying below. At the contact the gabbro has crumbled away, so the actual contact line could not be seen, but the two rocks were found within an inch of each other. There seems to be no change in either rock near the contact.

In the N. E. ¼ of S. E. ¼ and S. E. ¼ of N. E. ¼ sec. 3, T. 63–4, just north of the island mentioned above, there is a hill composed of a dark fine-grained rock (No. 229). This is cut through and through by numerous, irregular, branching veins of the fine red syenite (No. 230); these vary from two feet to half an inch in width, and even run out to needle-points. No. 229 seems to be a syenite, like the red syenite, but the hornblende makes up so large a part of it that the rock appears almost black. It is different from the dark rock seen in the syenite on the north side of Found lake. No. 231 shows Nos. 229 and 230 in contact; the contact is a distinct and sharply defined line, and in no place were the two rocks found to grade into each other.

The rest of the lake shore was examined; gabbro was found in many places, especially along the eastern shore. On the west shore, near the centre of sec. 2, T. 63–4, were two exposures of No. 229 cut as above described by fine red syenite similar to No. 228. At the extreme northeastern corner of the lake, in the S.W. ¼ of sec. 31, T. 64–3, the red syenite again occurs. At the portage (S. E. ¼ of sec. 35, T. 64–4) going north from lake Ida Belle the gabbro was cut by veins of fine red syenite (No. 232).

FROM LAKE IDA BELLE TO OGISHKE-MUNCIE LAKE.

Narrow lake. This is a narrow irregular lake in secs. 25, 26, 35, and 36 of T. 64–4; it is a mile and a half long (north and south), but not more than a quarter of a mile wide. It is 15 feet below lake Ida Belle. The shores are densely wooded, the timber being mostly spruce, birch and jack pine. The portage from lake Ida Belle is in the S. E. ¼ of sec. 35; it is well cut and only about an eighth of a mile in length. Gabbro occurs on the west shore in the N. E. ¼ of sec. 35. On the west shore (S. E. ¼ of N. E. ¼ sec. 26) near the north end of the lake is what seems to be a decayed condition of the gabbro (No. 233); this contains considerable biotite.

*Kiskadinna lake**. This lake is mostly in sec. 24, T. 64–4 and secs. 19 and 20, T. 64–3. It is 25 feet below Narrow lake. The shores are densely wooded. The northern arm, which is in the S. E. ¼ of sec. 13, T. 64–4 and the N. W. ¼ of sec. 19, T. 64–3, is shown on the plat as a separate lake, but it is only an arm of Kiskadinna lake. There are two short portages from Narrow lake to this lake along the stream that connects the two lakes. Not many rock exposures are to be seen along the shores of this lake; all those examined were gabbro. Gabbro also occurs on the south shore of the northern arm where the line between ranges 3 and 4 touches the shore.

Kiskadinna lake to Round lake. In the N. W. ¼ of S. E. ¼ sec. 13, T. 64–4 there is a short portage from Kiskadinna lake past a rapids in the stream† that flows from this lake through secs. 13, 11, 10, 3, and 2 of T. 64–4 into Round lake which is in the S. W. ¼ of sec. 35, T. 64–5. There are three rapids along this stream where short portages are made—in the N. W. ¼ sec. 13, S. W. ¼ Sec. 11, and N. W. ¼ sec. 2,—this last portage coming to Round

* This name is taken from Heinze Brothers "Map of the Vermilion Iron Range."

† This stream finally enters Gunflint lake at its western end.

lake. The stream is easily canoeable, being usually from 100 to 1,000 feet wide. The portages are well cut and seem to be used considerably in the winter time. The only rock seen along this stream was gabbro; this occurred in several places, as follows: near the centre of sec. 13, S. E. ¼ of sec. 11, on the portage in the S. W. ¼ of sec. 11, N. E. ¼ of sec. 10, S. W. ¼ of sec. 2, N. W. ¼ of sec. 2, and on the portage in the N. W. ¼ of sec. 2. Round lake is 60 feet below Kiskadinna lake.

Draper lake. This is a somewhat circular lake in the W. ½ of sec. 34 and the E. ½ of sec. 33, T. 65–4. It is 35 feet above Round lake. A portage of about half a mile connects these two lakes; it leaves Round lake at its northwestern corner. The gabbro occurs in several places along this portage. There are also many fragments of quartzyte on the portage, but no rock was found in place; these are probably from what has been termed Pewabic quartzyte found a short distance north of here. On the western shore of the lake, in the N. E. ¼ of sec. 33, there is an exposure of a muscovado-like rock (No. 233½).

Draper lake to Flying Cloud lake. From Draper lake we went through six small lakes to Flying Cloud lake. This plat (T. 65–4) is very inaccurate, and the route we took and the position of the lakes could not be definitely determined. Below, the lakes have been numbered from one to six, and the location given as near as possible.

Lake No. 1:—Near the centre of sec. 33, T. 64–5. Forty feet above Draper lake.

Lake No. 2:—N. W. ¼ of sec. 33, T. 64–5, not shown on the plat. Same hight as lake No. 1.

Lake No. 3:—This is probably Charley lake, which is in the N. ½ of sec. 32, T. 65–4. Fifteen feet above lake No. 2.

Lake No. 4:—Centre of sec. 29, T. 65–4. Not shown on the plat. Forty feet above lake No. 4. On the west side of the portage (this portage runs nearly north) from lake No. 3 there is a bluff 25 feet high and over 100 feet long; the front of the bluff is perpendicular. At the base near the centre there is a fine gray syenite (No. 234), forming the first eight feet of and extending for 25 feet along the foot of the bluff. Directly over the syenite and lying on it is the gabbro (No. 235) which composes most of the bluff. The change from the gabbro to the syenite was abrupt, there being no transition. The contact line was not easily seen as the face of the bluff was covered with lichens, but on chipping off small pieces of the rock the syenite and gabbro

were seen within an inch of each other. The syenite is very much finer than the Saganaga syenite found on the north shore of Gunflint lake. Just across the portage-trail from this bluff of syenite and gabbro there is one exposure of "muscovado" (No. 236) similar to No. 233½. A little island in the southern part of lake No. 4 is made up of a fine gabbro (No. 237) that seems to contain considerable olivine.

Lake No. 5:—E. ½ of sec. 30, T. 65–4. Not shown on the plat. This is a small lake, not more than a quarter of a mile across. Same hight as lake No. 4.

Lake No. 6:—S. W. ¼ of sec. 30, T. 65–4, and S. E. ¼ of sec. 25, T. 65–5. 25 feet below lake No. 5.

Flying Cloud lake:—This lake is about a mile in length, and lies in the S. ½ of S. ½ of sec. 25, and a small portion is in the N. W. ¼ of sec. 36, T. 65–5. 30 (?) feet below lake No. 6.

On the south shore near the east end of the lake (S. E. ¼ of S. E. ¼ sec. 25) there is a low ridge of dark, almost black, quartzyte running east and west. This quartzyte stands vertical, and the strike, as near as could be estimated without the needle, which is here much disturbed, is about east and west. The bedding is very plainly seen, especially on the weathered surfaces; this is caused by bands, which contain varying proportions of the two minerals of the rock,— quartz* and magnetite. The specimens collected (No. 238) fairly represent the rock, which is so rich in magnetite that it would make a fair iron ore. The principal exposure is in a vertical north facing wall, 12 feet high and 40 feet long, but several other smaller exposures are seen for 150 feet east of this. At the foot of the ridge is an outcrop of greenstone (No. 239). It seems as if the quartzyte overlies the greenstone, but this could not be positively determined (however, this is found to be the case about a mile west of this point). This quartzyte is the Pewabic quartzyte described in the 16th annual report, and the greenstone is probably the same as that mentioned in connection with the quartzyte.

From Flying Cloud lake we went southwest for about two miles along a stream — making four short portages — to Kakego lake. On the north side of this stream, a short distance west of the first portage from Flying Cloud lake (probably in the S. E. ¼ of S. E. ¼ sec. 26, T. 65–5), the Pewabic quartzyte again occurs; here it is fully as rich in iron as seen at any other place. This

* It is quite probable that there is also olivine in the rock.

is shown by No. 240. It dips south about 40°. Twelve feet north of this quartzyte is a low outcrop of greenstone (No. 241); this is much darker and heavier than No. 239 and apparently contains considerable iron. The position and dip of the quartzyte would bring it over the greenstone. The contact between the two rocks was covered by soil. On the south side of the stream is a ridge, 50 feet high, of the quartzyte dipping south about 50°. No. 242.

On the east end of the second portage from Flying Cloud lake the quartzyte is again seen; here it dips south 45°. On the west end of the portage the quartzyte is found lying on the greenstone (see Fig. 5). This is probably in the N. W. ¼ of N. E. ¼ sec. 35, T. 65–5. The contact is abrupt and there is no transition from one rock to the other. Both rocks seem to be unchanged near the contact, except that the greenstone is a little decayed. The Pewabic quartzyte, dipping south 45°, is shown by No. 243, which was taken within six inches of the contact. The greenstone is shown by No. 244; this seems to be similar to No. 239.

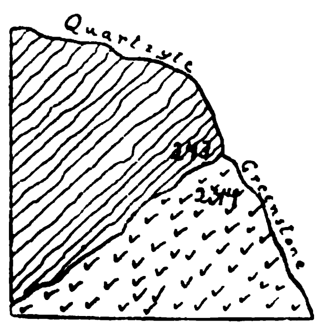

Fig. 5. *Pewabic quartzyte lying on greenstone, N. W. ¼ of N. E. ¼ sec. 35, T. 65–5.*

SHOO-FLY LAKE.*

This lake is in the S. E. ¼ of sec. 11 and the N. E. ¼ of sec. 14, T. 64–7. On the little point, in the N. E. ¼ of N. E. ¼ sec. 14, there is a fine-grained condition of the gabbro (No. 245), and on the east side of the lake near the southern end there is a precipitous cliff of the same rock rising 50 feet above the water,

*The following notes were taken on a trip from Knife lake through Kekequabic, Shoo-fly, Fraser, Thomas, Alice and Wilder lakes, thence along the Kawishiwi river to the S. E. ¼ of sec. 3, T. 62–9, and then through Gull lake to Mishiwishi lake.

From Shoo-fly lake a portage of a third of a mile runs south to a small lake, not shown on the plat, in the S. W. ¼ of sec. 13, T. 64–7. On the west side of this lake near the northern end there is an outcrop of gabbro (No. 246); this is finer than the ordinary gabbro. On the west side of the lake near the southern end is another outcrop of gabbro (No. 247) which seems to be a decayed condition of No. 246. From the southern end of this lake a portage runs south for about a third of a mile and reaches Fraser lake in the N. W. ¼ of N. W. ¼ sec. 24, T. 64–7.

FRASER LAKE.

Fraser lake is mostly in secs. 22, 23 and 24 of T. 64–7. On the north side of the lake in the S. E. ¼ of S. W. ¼ sec. 14, T. 64–7 there are several exposures of iron ore;* these were examined rather carefully. About 150 yards north of the shore, where it is cut by the line between secs. 14 and 23, is a small pit, four feet deep. At the bottom of this pit is found quite a rich olivinitic iron ore (No. 248); this disturbs the needle but slightly and seems to be mostly menaccanite rather than magnetite. On the north this comes in contact with a wall of rock (No. 249) composed of large crystals of hornblende (?) that is almost fibrous; in this there are parallel bands of iron ore (Nos. 250 and 251) which run east and west and dip south about 80°. No. 250 is similar to the ore in the pit, while No. 251 is distinctly a magnetic quartzyte and shows the bedding plainly. A few rods northeast of this pit, and at the top of the steep northward slope, is another exposure of olivinitic iron ore (No. 252); this appears similar to the ore in the pit, but affects the needle very strongly, thus probably being mostly magnetite. This mass of iron ore at its western edge comes into direct contact with a hornblende rock (No. 253) which is a less decayed condition of No. 249. The hornblende rock is here also in contact with a fine "muscovado" (No. 254) which shows a few large crystal faces of feldspar, half an inch or more in length. Very little of these two rocks was seen and their relation to each other was not determined. The contact line is irregular and there is no transition from one to the other, nor is there any sign of alteration in either rocks near the contact. A few small areas in this hornblende rock were quite rich in iron, as shown by Nos. 255 and 256, but the limits of these areas were rather sharply defined. The observations

*This is the place where an attempt was made to mine for gold several years ago.

were made on a ridge which runs east and west; it was examined for 100 yards on each side of the above mentioned pit. The north side of the ridge is rather steep and at its foot occurs the muscovado, here represented by No. 257. As far as exposed the top of the ridge is composed of the hornblende rock (Nos. 249 and 253); this holds many masses and bands of magnetitic quartzyte. The bedding in the quartzyte is usually very distinct; in all the places examined it runs east and west, but within ten feet the dip varies from the vertical to about 45° south. The masses of iron ore where Nos. 248 and 252 were obtained contain very little quartz and show no evidence of bedding. The line of contact between the quartzyte and the surrounding rock is usually distinct and very irregular; there was no blending of the two rocks. No. 258* shows the quartzyte, and in the specimens numbered 259 the bedding is plainly seen. No. 260 shows the contact of the quartzyte and the surrounding rock.

In the N. W. ¼ of N. E. ¼ sec. 23, about a quarter of a mile west of the previously described locality, is a ridge running east and west; this is probably an eastward continuation of the ridge mentioned above. On the south side near the base of the ridge and about 50 feet from the lake a rather fine, decayed, gabbro-like rock (No. 261) occurs; this is exposed in several places; it has a rough bedded structure (the beds being from 6 to 12 inches thick) which is nearly horizontal. On the north side of the ridge and near its foot is a small exposure of iron ore (No. 262); it has a tendency to split along parallel plains which are vertical and run east and west. Within ten feet of this ore the quartzyte is seen. The ridge at this place is made of quartzyte which was followed eastward for 50 yards, where the ridge ends abruptly. The bedding is very nicely seen along the weathered surfaces; it is caused by bands of almost pure quartz alternation with bands rich in magnetite. Some of these bands are shown by Nos. 263, 264 and 265. Throughout the fifty yards that the quartzyte was followed, except in one small area where the beds had been broken and bent, the strike and dip were constant, the former being almost east and west, and the latter south 75°. At the eastern end of the ridge a band two feet wide, of a fine muscovado-like rock (No. 266) occurs interbedded with the quartzyte; this rock was traced for over 30 feet; it has a tendency to a rough cleavage which is parallel with the quartzyte bedding. On the

*No. 258 was taken from the quartzyte near this; it is a bunch of the crystals of the hornblende rock, but they seem to be mostly magnetite.

south side of the ridge, but not within 30 feet of any quartzyte, is also found an outcrop of the iron ore (No. 267) which has weathered into thin parallel sheets conformable with the quartzyte.

The quartzyte described at these two localities on Fraser lake is decidedly like the Pewabic quartzyte. Evidently the gabbro, which covers this section of country, has been worn away and a much disturbed portion of the underlying quartzyte exposed. The quartzyte was not seen in contact with, nor in fact near any of the ordinary labradorite gabbro, but this gabbro has been seen on all sides of it at places usually less than a mile distant.

THOMAS LAKE.

This lake is in secs. 27, 28, 29, 32, 33 and 34 of T. 64–7, and secs. 5 and 6 of T. 63–7. There is some good white pine along the southern shore of the lake; several claim cabins were seen here.

The iron ore, shown on the map (in the 15th annual report) as occurring on the north side of the lake in secs. 27 and 28, was not found, although the locality was carefully examined. The only iron seen was a small amount of menaccanite in the gabbro (No. 269); this specimen was found about a quarter of a mile north of the lake in the N. E. ¼ of sec. 28.

On the north side of the mouth of the little bay, which is near the centre of the W. ½ of sec. 27, there is a bluff 40 feet high, of muscovado (No. 270) holding irregular blotches of a light colored feldspar.

On the lake shore in the N. E. ¼ of sec. 29, on a little point that is about half way between the meander corner on the line between secs. 28 and 29 and the stream that flows toward Ima lake, is a low outcrop of rock (No. 271) similar to the hornblende rock found at Fraser lake. Here were many angular fragments of quartzyte (similar to the Pewabic quartzyte); one specimen (No. 272) was taken to show how plainly the banding appears on a weathered surface. A few feet back from the shore is an outcrop, two feet high, of magnetic iron ore (No. 273);* this is composed of almost pure magnetite with a little olivine. This ore was not seen in contact with any other rock, but it contains a few of the crystals that make up the hornblende

* This is probably the ferruginous gabbro mentioned in the 15th annual report, page 360, but no hammer marks were seen here. (It was this which was intended to be represented on the map. N. H. W.)

rock. No bedding could be seen. On farther search a low outcrop of quartzyte, similar to that seen at Fraser lake, was found about 50 yards from the shore. By pulling away the moss and soil this rock was exposed for twelve feet. It lies nearly horizontal, dipping south about 10°. Nos. 274 and 275 show this quartzyte. As the shore at this point is low and there is very little rock exposed, the relations of the hornblende rock, the iron ore and the quartzyte could not be determined.

LAKE ALICE.

From the extreme southwestern corner of Thomas lake a portage, of less than a quarter of a mile, leads southwest to Gabiskamak* lake, which is an irregular lake lying in sec. 6 of T. 63–7. The shores of this lake, except a small portion at the northern end, have been burnt and are now partially covered by bushes 8 to 10 feet high. There were many rock outcrops along the shores; all of those visited were gabbro, and the others appeared to be the same.

From the south end of Gabiskamak lake a portage of half a mile leads south to the arm of Wilder lake that extends into the S. E. ¼ of sec. 7, T. 63–7. Gabbro was seen in several places on the portage; also on the west shore of the arm of Wilder lake. The north shore of the Kawishiwi river was examined from Wilder lake to lake Alice; no rock was seen except gabbro and there were many exposures of this. Between these two lakes both shores of the river have been burnt and are now covered with small birches, poplars and jack pines.

Lake Alice lies mostly in secs. 9, 10, 15, 16 and 21 of T. 63–7. It is four feet above Wilder lake and is connected with it by two miles of river in which there is one fall; this is in the N. E. ¼ of N. W. ¼ sec. 20, T. 63–7. The Chippewa name for this lake is Pe-na sagiagan or Partridge lake. The island crossed by the line between secs. 9 and 16 has not been burnt; also the N. W. ¼ of S. E. ¼ sec. 15, where there is a claim cabin and some Norway pine. The rest of the shore has been burnt and is now covered with young birches, jack pines, and poplars. From the end of the bay in the N. W. ¼ of sec. 22 there is a portage leading east; there is also one, leading east, leaving the lake in the N. W. ¼ of S. E. ¼ sec. 10. From the extreme northern end of the lake a short

*This is the Chippewa name of the lake; I do not know its meaning.

portage leads to a small lake, on the south shore of which the gabbro is exposed. Lake Alice, and especially the eastern side, was rather carefully examined, stops being made about every 200 or 300 yards (the bay in the N. E. ¼ of sec 9 was not entered); no rock was found except the ordinary labradorite gabbro; this was seen in very many places; No. 277 is a sample from the S. E. ¼ of N. W. ¼ sec. 15. In one place on the east side of the long bay in sec. 15 the gabbro (No. 276) is of a decidedly pinkish color; the labradorite crystals have a pinkish tinge and there are blotches of a very soft, brick-red mineral, probably an oxide of iron. Search was made back from the shore for more of this pink gabbro, but none was found.

LAKE ALICE TO MISHIWISHIWI LAKE.

The bay of Wilder lake which lies in sec. 13, T. 63-8, was not entered by the survey two years ago; and so it was examined on this trip; no rock was seen except the gabbro.

From Wilder lake the Kawishiwi river was followed to the little bay in the N. W. ¼ of S. E. ¼ sec. 3, T. 62-9; here a portage of about two miles was made southeast to Gull lake. There is no portage route through this way,—only a very poor trail which is used by the Indians in their winter trapping. On the way three ponds were crossed; one in the S. ½ of sec. 3, T. 62-9, one in the N. E. ¼ of sec. 9, and one on the line between secs. 9 and 16;—no rock exposures were seen on these ponds, but there were exposures of gabbro in the N.W. ¼ of sec. 10 and the N. W. ¼ of sec. 16.

Gull * lake is a narrow body of water extending northeast and southwest in sections 16, 17, 19 and 20 of T. 62-9. The shores are closely covered with spruce and jack pine. The west side of the lake was examined; all the rock seen was the ordinary gabbro. From the southwest corner of this lake a fair portage, over a mile in length, leads southwest and reaches Mishiwishiwi lake where the line between secs. 24 and 25, T. 62-10 crosses the shore. Gabbro occurs along this portage.

PINE ISLAND, VERMILION LAKE.

A section was made across Pine island, on the line between ranges 15 and 16, in order to examine a hill of jasper reported

* The Chippewa name is Gaiashk (Gi-äshk) sagaigan or Gull lake.

to be there. The writer crossed the island on this line and also went west from the line for a mile, near the centre of the island, but found no jasper hill, nor any indications of jasper. The rocks seen on the section across the island are given below.

At the north side of the island is a hill, rising 40 feet above the water; this is made of vertical, rather siliceous, sericitic schist (No. 284); the strike is E. 15° N. From this hill a swamp, where there are no rock exposures, extends for nearly one-fourth of a mile south of the corners of T. 62–15, 62–16, 63–15 and 63–16. At the south end of the swamp is a low (six feet high) ridge of sericitic schist (No. 285); strike E. 20° N., vertical. Just north of the quarter post there are three ridges running east and west. The first ridge is composed of a greenish rock, which on the north side of the ridge is quite schistose and somewhat sericitic (No. 286); strike E. 10° N., vertical; on the south side the rock is more massive and graywacke-like (No. 287). The second ridge is made of a rough sericitic schist (No. 288); strike nearly east and west, vertical. No. 289 is from the third ridge; it is harder, greenish, and perhaps somewhat chloritic. South of the quarter post, and about an eighth of a mile from the lake, the following rocks were seen; strike E. 15° N., vertical. No. 290, light gray argillaceous slate; Nos. 291, 292 and 293, coarser and rather sericitic conditions of the same; Nos.294and295, light gray arigllaceous slate. No. 296 shows a more siliceous condition of the slate. At the lake shore there are fine argillaceous slates* (No. 298); these vary from black to gray; the slaty structure and the black and gray bands are parallel; strike E. 15° N., and dip 80° to the north. No. 297 shows the gray slate a few feet from the shore.

III. Summary.

No generalization or theories would here be in place, but it may, perhaps, be admissable for the writer to give a very brief summary statement of the bearing of some of the facts in the foregoing notes upon the general geology of the region traversed. The following remarks relate, more or less, to the great gabbro sheet, which covers so much of that part of Minnesota north of lake Superior.

The fine red syenite, or "red rock" of former reports, was seen in several places on lake Ida Belle in contact with the gabbro. In one place (see fig. 4) the gabbro was in contact with

*Mentioned in 15 An. Rep., p. 303; No. 921.

and was unquestionably overlying the syenite; but in other places veins and dyke-like forms of what certainly appears to be the same syenite cut through the gabbro. The syenite has the appearance of an eruptive rock, and the general impression left on one, by seeing the outcrops on this lake, is that the syenite is of more recent date than the gabbro. The two rocks are very distinct and in no place were seen to grade into each other; where they were seen together the contact was a well defined line.

The syenite found on the gabbro at Winchell lake is not the same as that just mentioned.

The iron ore and magnetic quartzyte (of which the ore is a part) found at Fraser and Thomas lakes are undoubtedly disturbed portions of the Animike beds now included in the gabbro. It is probable that they have not been moved far from their original position, and that, consequently, at this place the gabbro sheet is of a comparatively small thickness. It seems that all the ore at this place is from the quartzyte and that that portion which is but slightly magnetic has become charged with titanium from the gabbro. In connection with this quartzyte is found a peculiar rock that is made up of coarse and almost fibrous crystals of what is probably hornblende. This rock, as far as the writer knows, has been found in this region nowhere except in connection with this quartzyte and then only when the quartzyte was close to or in contact with the gabbro. The quartzyte south of Birch lake, at Chub (Akeley) lake and at Thomas and Fraser lakes also shows this.

IV. List of, and Notes on, the Typical Rocks of each of which 25 Specimens were Collected.

These specimens are, in many cases, from the exact spot from which the original specimens were collected and described, the writer having visited many of these localities with Prof. Winchell on two of his trips through this region. Some of the specimens from localities, not before visited by the writer, may not always be exactly the same as the original specimens, but they are very nearly the same,—as near as could be found from the notes given him. Only brief descriptions of many localities were accessible in the field, as the 16th annual report had not then been printed.

After each number the place where the original description can be found, is given.*

No. 744, (84):—Ogishke-Muncie conglomerate from Camper's island, Ogishke-Muncie lake; S. E. ¼ of S. W. ¼ sec. 23, T. 65–6. The specimens were taken from the southwest corner of the island. They show the matrix of the conglomerate, with sometimes a few of the smaller pebbles. The specimens collected are coarser and not as green as the original No. 744. 10th An. Rep., p. 91.

No. 751:—Hornblende porphyry, S. E. ¼ of sec. 30, T. 65–6; Kekequabic lake. No specimens of this were collected, as the rock was not found in place by the writer. It is similar to No. 1059 (97), except that the ground mass is inclined to brownish, while No. 1059 is yellowish green. See No. 1059 10th An. Rep., p. 92.

No. 868, (278):—Green chloritic schist embracing fragments of jaspilyte, north of Cady house, Tower. This rock evidently grades into No. 908 (281). 15th An. Rep., p. 267–8.

No. 892, (279):—Rough, scarcely banded jasper, north wall Stone mine, Tower. Owing to changes in the walls of the mine, this rock was not seen 75 feet below the surface; the specimens collected were taken about 25 feet below the rock surface. 15th An. Rep., p. 256.

No. 903, (280):—Red jasper with darker bands of iron ore; Stone mine, Tower.

No. 908, (281):—Matrix of conglomerate occurring north of the Cady house, Tower. 15th An. Rep., p. 269.

No. 916, (282):—Breccia, now converted to hematite and a floury white mineral; Breitung mine, Tower. 15th An. Rep., p. 250.

No. 921, (283):—Black or purplish-black clay slate, S. W. ¼ of S. W. ¼ sec. 6, T. 62–15; south shore of Pine island, Vermilion lake, a few feet east of the line between ranges 15 and 16. See notes on Pine island in this report. 15th An. Rep., p. 303.

No. 950, (128):—Siliceous schist or bedded quartzyte from "Silver City," N. E. ¼ of sec. 32, T. 63–11. The specimens were obtained from the shore, forty feet nearer the rapids than the southern tunnel is. 15th An Rep., p. 329.

No. 954, (114):—Coarse gabbro, east side of Birch lake. The specimens were taken from the same exposure from which the

* These are the numbers given by Prof. Winchell in the 10th, 15th and 16th annual reports. The numbers in parentheses and all under 300 are those given by the writer.

original specimen came. In the description (16th An. Rep.) this locality is given as the N. W. ¼ of sec. 20, T. 61–11, and in the catalogue of rock samples as the N. W. ¼ of Sec. 17. Judging from distances to known points (this town has not been surveyed) the writer thinks that the N. W. ¼ of sec. 17 is the right place. 15th An. Rep., p. 332.

No. 958, (121):—Breccia of mica-schist cemented by granite from the little point in the N. E. ¼ of S. E. ¼ sec. 21, T. 61–12, Birch lake. Where the mica-schist showed the schistose structure to the best advantage, the rock was too much decayed for good specimens. 15th An. Rep., p. 333.

No. 960:—See No. 1138.

No. 963, (123):—Fine-grained red syenite, resembling the "red rock" of Grand Marais, from the S. W. ¼ of S. W. ¼ sec. 24, T. 61–12, Birch lake. The specimens were collected just east of the line between secs. 23 and 24, and about 300 feet back from the lake shore. 15th An. Rep., p. 336.

No. 979, (111):—Fine syenite from the "Palisades," N. W. ¼ of S. W. ¼ sec. 4, T. 62–10. The specimens are from near the southern end of the "Palisades" and about 20 feet above the water. The rock varies some and has an almost gneissic structure. The specimens collected represent the prevailing variety; this grades into No. 112, which is gray, and into No. 113, which is coarser. 15th An. Rep., p. 342.

No. 989, (101):—Fine grained, slightly micaceous quartzose rock from the south shore of the Kawishiwi river in the N. W. ¼ of N. W. ¼ sec. 27, T. 63–10. 15th An. Rep., p. 352.

No. 991, (102):—Gray, red-weathering gneissic rock from an island in the N. W. ¼ of N. W. ¼ sec. 27, T. 63–10, Kawishiwi river. The southern part of the island is composed of this rock, but on the central and northern parts the rock has many darker hornblendic bands which show very plainly on the weathered surface (No. 103). One much darker hornblendic band, about a foot in width, was seen; this (No. 104) seemed to be distinct from the others, which graded into one another. No. 991 also showed banding on weathered surfaces. 15th An. Rep., p. 352.

No. 994, (105):—Reddish chloritic syenite; N. E. ¼ of N. W. ¼ sec. 27, T. 63–10; south shore of Kawishiwi river. This rock is hardly a red syenite like the original No. 994, but in places it is reddish,—see No. 107, which is similar to the original No. 994; not enough of this reddish rock could be found for the specimens. This rock (No. 105) seems to grade into No. 108 and

No. 109; the latter has some biotite and the exposures show a rather distinct bedding, while the exposures of No. 105 do not. Lenticular pieces of a greenish chloritic schist (No. 110) are found in a few places in No. 105. 15th An. Rep., p. 353.

No. 1044, (85):—Gneissic (syenitic?) rock, south shore of the little bay at the southeast side of Kekequabic lake, S. E. ¼ of S. W. ¼ sec. 2, T. 64–7. The specimens were taken from the only outcrop, on the south side of this bay, where hammer marks were seen. The rock contains many small dark masses, apparently chloritic, as shown by No. 85; none of these were over an inch in diameter. In a few places this dark mineral is collected into rather indistinct vein-like forms, but there is no marked contrast between these "veins" and the surrounding rock. 15th An. Rep., p. 361.

No. 1049, (87):—Biotite gabbro, somewhat pebbly, east side of sec. 4, T. 64–7, Kekequabic lake. The water was so high that the specimens could not be collected in the bay in the east side of sec. 4, so they were taken from the N. E. ¼ of the S. E. ¼ of sec. 4; here the rock seems to be the same as in the bay. The pebbly structure of the rock is shown only where it has been water worn. At this place the gabbro lies on some gray earthy slate. The slate was down at the water's edge and there was only a very small area of it, so not much could be determined concerning it. No abrupt contact could be seen between the two rocks; there was a transition, occupying perhaps two feet, from the gray earthy slate (No. 88), through Nos. 89 and 90, to the gabbro (No. 87). 15th An. Rep., p. 364.

No. 1050, (91):—Fine-grained gabbro from the top of the same bluff, as from which No. 1049 was taken. The specimens were taken about 35 feet above the water. N. E. ¼ of S. E. ¼ of sec. 4, T. 64–7, Kekequabic lake. 15th An. Rep., p. 364.

No. 1059, (97):—Hornblende porphyry from the north shore of Kekequabic lake, N. E. ¼ of sec. 36, T. 65–7. Within a few inches this rock varies much, the hornblende crystals becoming smaller and fewer in number and sometimes almost wanting, as shown by the small specimen (No. 97). The rock is very hard and tough and rings like iron when struck by the hammer; it frequently contains crystals of iron pyrites. See No. 751. 15th An. Rep., p. 367.

No. 1068, (70):—Doleryte, from N. E. ¼ of sec. 24, T. 65–6; about a quarter of a mile southeast from the shore of Ogishke-Muncie lake. This rock contains considerable of a pinkish min-

eral (probably calcite); this mineral also occurs in small veins or fissures in the rock, shown by No. 71. 15th An. Rep., p. 371; also, 16th An. Rep., p. 95–6.

No. 1073, (69):—Coarse-jointed massive rock, apparently igneous, mouth of Ogishke-Muncie creek, N. E. ¼ of S. E. ¼ sec. 26, T. 65–6; Ogishke-Muncie lake. This rock overlies the following, which see. In some places the rock has cherty spots, as shown in the smaller specimen (No. 69), probably pieces of the slate (No. 1074). 15th An. Rep., p. 372.

No. 1074, (68):—Fissile black slate, baked and closely jointed, mouth of Ogishke-Muncie creek, N. E. ¼ of S. E. ¼ sec. 26, T. 65–6; Ogishke-Muncie lake. No specimens could be obtained at the contact with the overflowing rock (see above, No. 1073), as here the slate was much broken; the specimens collected are from the point made by the creek and the lake shore, which point is but a few yards west of No. 1073. At this place the slate plainly dips 20° S. of E. at an angle of about 80°. No. 68A was obtained just below the contact, while No. 68 B is from a piece of the slate included in the overlying rock. The slate has, in places, a decidedly conchoidal fracture as shown by No. 68C. The weathered surfaces on the specimens marked 68 show an apparently sedimentary banding which is parallel with the slaty structure. 15th An. Rep., p. 372.

No. 1094, (86):—Gray porphyritic rock, representing an altered conglomerate, from the point which has the corners of secs. 29, 30, 31, and 32, T. 65–6; north shore of Kekequabic lake. The specimens were taken from the southeast side of the point, or in the N. W. ¼ of N. W. ¼ sec. 32, T. 65–6. No. 86 shows a small one of the greenish nodules or pebbles. 15th An. Rep., p. 368; 16th An. Rep., p. 100.

No. 1098, (96):—Conglomeritic chlorite schist, from the north shore of Kekequabic lake where it is crossed by the line between T. 65–6 and 65–7. The small amount of the rock left uncovered by the porphyry and its decayed condition made it rather difficult to get good specimens. 15th An. Rep., p. 367.

No. 1100, (93):—Reddish syenite, island in sec. 3, T. 64–7, Kekequabic lake. No. 1100 is described from the most westerly island in the lake, but this island, which is just east of the point in the S. W. ¼ of N. W. ¼ of sec. 3, is small and low and is made up of a condition of the green chlorite schist (No. 94); the small island, just northeast of the last, seems to have no rock in place, but along the shore are many fragments of feldspar porphyry

(No. 95). The specimens (No. 1100) were taken from a larger island in the S. E. ¼ of N. W. ¼ sec. 3, just west of Animike island. 15th An. Rep., p. 362.

No. 1109, (100):—Felsitic schist, from the portage from Fall lake to Newton lake, S. W. ¼ of sec. 3, T. 63–11. The specimens were collected from the south, or Fall lake, end of the portage. 15th An. Rep., p. 356.

No. 1128, (129):—"Gabbro" cut by intrusive syenite; N. W. ¼ of S. E. ¼ sec. 6, T. 62–11, White Iron lake. See No. 1129, 15th An. Rep., p. 331.

No. 1129, (130):—Intrusive granite (syenite), N. W. ¼ of S. E. ¼ of sec. 6, T. 62–11, White Iron lake. Nos. 1128 and 1129 are from the place frrom which Dr. Wadsworth took the original specimens. The "gabbro" is not similar to the ordinary labradorite gabbro; it is perhaps a biotitic diabase. No. 131 is the syenite taken from a dike in the diabase. No. 1129 (130) is, I think, a fair sample of the syenite found about White Iron lake. 15th An. Rep., p. 331.

No. 1132, (127):—Black hornblende gneiss, east shore of White Iron lake, just south of the line between secs. 6 and 7 of T. 62–11. A set of specimens could not be obtained, as the gneiss only occurred in small masses in the syenite and here the surface was worn smooth by glaciation. No. 127 shows the contact between the gneiss and the syenite. 15th An. Rep., p. 331.

No. 1134, (124):—Micaceous "gabbro," or rather biotite hornblende schist, cut by veins of granite (syenite); N. W. ¼ of S. E. ¼ sec. 12, T. 62–12, east side of White Iron lake. The specimens were collected from the place where Dr. Wadsworth obtained the original ones. About 70 yards west of this place is the outcrop described by Dr. Alex. Winchell in the 15th annual report (see p. 77, halt 211). Here the hornblende schist is represented by No. 125, and the granite by No. 126. These two outcrops are connected by a ridge, in which the rock is not exposed, but the schist found at the east end (No. 124) is probably the same as that at the other end (No. 125). 15th An. Rep., p. 331.

No. 1137, (122):—Fine-grained gabbro, looking like diabase, from a point a short distance west of the line between secs. 24 and 25, T. 62–12; north shore of Birch lake. This seems to be a finer-grained condition of the ordinary labradorite gabbro. The specimens were obtained from the west side of the little bay in the S. E. ¼ of S. W. ¼ sec. 24. 15th An. Rep., p. 332.

No. 1138. Ferruginous olivine rock, about 15 rods from the shore; S. E. ¼ of S. W. ¼ sec. 24, T. 62-12; Birch lake. No specimens of this were collected, as a set of 25 (No. 960) was collected in 1886. It is a part of the great quartzyte formation (Animike) lying along the southern side of the Giant's range. 15th An. Rep., pp. 332 and 335.

No. 1278, (8):— Kewatin schist, mouth of the creek, east end of the long bay, north side of Gunflint lake. This is the most eastern exposure of the Kewatin on Gunflint lake. The rock at the shore was so cracked and broken that only four specimens were collected; these are marked 1,278A (8A). The rest of the specimens were taken from a low outcrop about 10 rods back from the shore; the schist here is similar to that at the shore, but is not so much decayed and is apparently more siliceous. 16th An. Rep., p. 67.

No. 1282, (9):—Gray gneissoid rock, slightly porphyritic; shore of the long bay, north side of Gunflint lake. The specimens collected do not answer exactly to the description, but they are a part of the same rocks. 16th An. Rep., p. 68.

No. 1283, (10):— Porphyrel; bluff north shore of Gunflint lake. The specimens were taken from a vertical cliff on the lake shore, about three-fourths of a mile west of the east end of the long bay. 16th An. Rep., p. 68.

No. 1312, (60):—Fine-grained trap, from the west side of the narrows of Gunflint lake; S. E. ¼ of N. W. ¼ of sec. 19, T. 65-3. In places this trap holds crystals of feldspar which sometimes are an inch long.

No. 1316, (46):—Syenitic gneiss from the north side of Blackfly bay, Gunflint lake. 16th An. Rep., p. 73.

No. 1318, (61):—Diabase dike in the syenite, first falls of Gunflint river, north of Gunflint lake. See this report under Gunflint lake.

No. 1340, (43):—Purplish-gray, vitreous quartzyte (Pewabic quartzyte), ⅛ mile west of the ore pit, Chub lake; N. E. ¼ of sec. 29, T. 65-4. 16th An. Rep., p. 85.

No. 1371, (72):—"Marble" from east side of Ogishke-Muncie lake; N. E. ¼ of sec. 24, T. 65-6. The place where the specimens were collected is probably where the section (p. 371, 15th An. Rep.) was made. No. 73 shows a softer, more schistose portion of No. 72. No. 74 are some of the angular pieces included in No. 72. No. 75 shows a soft greenish (probably talc) mineral found in the "marble" (No. 72). 16th An. Rep., pp. 95 and 96; also, under No. 1069, 15th An. Rep., p. 371.

No. 1409, (92): — Chloritic schist from the small island near the north shore and just west of the narrows of Kekequabic lake. This island is in the N. W. ¼ of N. E. ¼ sec. 36, T. 65–7; there is a much smaller island just east of it and also one north of it. 16th An. Rep., p. 102.

No. 1428, (98);—Dark siliceous slate, from the E. ½ of N. E. ¼ sec. 28, T. 65–7; Knife lake. This slate varies from grayish to black; the specimens collected are gray, as this colored rock made up most of the point. 16th An. Rep., p. 109.

No. 1436, (99);—Micaceo-syenitic gneiss, from Opinin island, Basswood lake. This island is in sec. 10 (probably N. E. ¼ of S. W. ¼), T. 64–10. 16th An. Rep., p. 110.

Twenty-five specimens of the *conglomeritic syenite* from Saganaga lake were also collected. The writer numbered these 66. No. 67 shows the syenite. This rock is described by Dr. Alex. Winchell in the 16th An. Rep., pp. 219–222, and p. 334; also in the American Geologist, vol. III, No. 3, p. 153.

V. Barometrical Elevations.

On the trip from Gunflint lake south to Brulé lake and north to Ogishke-Muncie lake the elevation of each lake was noted from readings of an aneroid barometer. The following table gives the elevation of each lake above lake Superior and also above the sea level. The elevation of Gunflint lake (the starting point) above lake Superior,—1,052 feet,—is taken from the 9th An. Rep., p. 81. The highest water noted is Lost lake which is 1,427 feet above lake Superior, or 2,029 feet above the sea.

	Feet above lake Superior.	Feet above the sea.
Gunflint lake	1052	1654
Loon lake (195 ft. above Gunflint lake),	1247	1849
Mayhew lake (110 feet above Loon lake),	1357	1859
Iron lake (same hight as Mayhew lake),	1357	1859
Portage lake (25 ft. above Iron lake),	1382	1984
Poplar lake (20 ft. below Portage lake),	1362	1964
Straight lake (25 ft. below Poplar lake),	1337	1939
Caribou lake (10 ft. below Straight lake),	1327	1929
Meed's lake (10 ft. above Caribou lake),	1337	1939
North Brulé lake (20 ft. below Caribou lake),	1307	1909
Stray lake (30 ft above North Brulé lake),	1337	1937
Gaskanas lake (15 ft. above Stray lake),	1352	1954
Winchell lake (30 ft. above Gaskanas lake),	1382	1984
Sham lake (15 ft. above Winchell lake),	1397	1999

	Feet above lake Superior.	Feet above the sea.
Lost lake (30 ft. above Sham lake),	1427	2029
Brulé lake (75 ft. below Lost lake),	1352	1954
Lake Georgia (6 ft. below Brulé lake),	1346	1948
Surveyor's lake (1 ft. above lake Georgia),	1347	1949
Found lake (same hight as Surveyor's lake),	1347	1949
Lake Ida Belle (30 ft. below Found lake),	1317	1919
Narrow lake (15 ft. below lake Ida Belle),	1302	1904
Kiskadinna lake (25 ft. below Narrow lake),	1277	1879
Round lake (60 ft below Kiskadinna lake),	1217	1819
Draper lake (35 ft. above Round lake),	1252	1854
Lake No. 1 (40 ft. above Draper lake),	1292	1894
Lake No. 2 (same hight as lake No. 1),	1292	1894
Lake No. 3 (15 ft. above lake No. 2),	1307	1909
Lake No. 4 (40 ft. above lake No. 3),	1347	1949
Lake No. 5 (same hight as lake No. 4),	1347	1949
Lake No. 6 (25 ft. below lake No. 5),	1322	1944
Flying Cloud lake (30 ft. below lake No. 6),	1292	1894
Kakego lake (65 ft. below Flying Cloud lake),	1227	1829
Clothes Pin lake (60 ft. below Kakego lake),	1167	1769
Gabemichigama lake (20 ft. below Clothes Pin lake),	1147	1749
Agamok lake (3 ft. below Gabemichigama lake),	1144	1746
Fox lake (30 ft. below Agamok lake),	1114	1716
Ogishke-Muncie lake (60 ft. below Fox lake),	1054	*1656
Wilder lake,	1102	‡1704
Lake Alice (4 ft. above Wilder lake),	1106	1708

VI. Catalogue of Rock Samples to Illustrate the Foregoing Notes; Collected by Uly. S. Grant During the Summer of 1888.

Most of these rock samples are of museum size; and in many cases more than one specimen was collected, to represent a certain number. This is especially true of the iron ores, of each of which several pieces were taken for analysis. The samples have been deposited in the rooms of the survey. They are numbered from 1 up to 298, inclusive; the figures are green,—paris green and shellac dissolved in alcohol being used; after each number the letter G is placed.

Nos. 132–146, inclusive, were placed on an island which was soon after overrun by a fire, and all the labels destroyed and the specimens discolored. These specimens have not been preserved:

*From figures in the 9th An. Rep., p. 84, Ogishke-Muncie lake is 1,611 ft. above the sea; and from the 15th An. Rep., p. 384, it is 1,507 ft. above the sea.

‡15th An. Rep., p. 384.

1. Magnetic iron slate and jasper, N. ½ of sec. 33, T. 66–6; Ottertrack lake; 80 rods south of the lake shore. P. 151.

2. Same as No. 1. P. 151.

3. Magnetic iron slate and jasper, N. E. ¼ of N. W. ¼ sec. 27, T. 66–6 (if the U. S. sections were extended northward); north shore of Ottertrack lake. P. 151.

4. Graywacke-like rock north shore of Ottertrack lake. just west of No. 3. P. 151.

5. Graywacke-like rock, north shore of Ottertrack lake, just east of No. 3. P. 151.

6. Coarse syenite, small island in the S. E. ¼ of S. E. ¼ sec. 13, T. 65–4; Gunflint lake. P. 152.

7. Hornblende schist in syenite; same locality. P. 152.

8. Sericitic schist, at the shore near the east end of the long bay on the north side of Gunflint lake. Same as No. 1278 (N. H. W.). P. 199.

8A. Same as No. 8, but apparently more siliceous. P. 199.

9. Gray gneissic rock, almost porphyrel; north shore of the long bay on the north side of Gunflint lake. Same as No. 1282 (N. H. W.). P 199.

10. Porphyrel, on the shore about three-fourths of a mile west of the east end of the long bay on the north side of Gunflint lake. Same as No. 1283 (N. H. W.). P. 199.

11. Sericitic schist, north shore of Gunflint lake; section I. P. 152.

12. Earthy schist, north of Gunflint lake; section I. P. 153.

13. Fine porphyrelloid rock, north of Gunflint lake; section I. P. 153.

14. A coarser condition of 13, north of Gunflint lake; section I. P 153.

15. A finer condition of 13, north of Gunflint lake; section I. P. 153.

16. Black slate, north of Gunflint lake; section I. P 153.

17. Trap rock, north of Gunflint lake; section I. P 153.

18. Fine trap from outer edge of dike, north of Gunflint lake; section I. P 153.

19. Trap from centre of same dike, north of Gunflint lake; section I. P 153.

20. Sericitic schist, north of Gunflint lake; section I. P 153.

21. Black slate, north of Gunflint lake; section I. P 153.

22. Fine gabbro, north of Gunflint lake; section I. P. 153.

23. Black slate, north of Gunflint lake; section I. P. 153.

24. Porphyrel, north of Gunflint lake; section I. P. 154.

25. Gray, somewhat micaceous schist; north of Gunflint lake; section I. P. 154.

26. Hornblende schist, north of Gunflint lake; section I. P. 154.

27. Hornblende schist, north of Gunflint lake; section I. P. 154.

28. Mica-schist, north of Gunflint lake; section I. P. 154.

29. Feldspathic schist, north of Gunflint lake; section I. P. 154.

30. Hornblende schist, north of Gunflint lake; section I. P. 154.

31. Hornblende schist, north of Gunflint lake; section I. P. 154.

32. Mica-schist, north of Gunflint lake; section I. P. 154.

33. Hornblende schist, north of Gunflint lake; section I. P. 154.

34. Syenitic gneiss, north of Gunflint lake; section II. P. 155.

35. Hornblende schist inclosed in gneiss, north of Gunflint lake; section II. P. 156.

36. Trap from dike in gneiss, north of Gunflint lake; section II. P. 156.

37. Magnetitic portion of this dike, north of Gunflint lake; section II. P. 156.

38. Gray earthy slate, north of Gunflint lake; section II. P. 157.

39. Porphyrel, north of Gunflint lake; section II. P. 157.

40. Schistose dike rock, north of Gunflint lake; section II. P. 157.

41. Finer portion of No. 40, north of Gunflint lake; section II. P. 157.

42. Porphyrel inclosed in dike, north of Gunflint lake; section II. P. 157.

43. Purplish-gray, vitreous quartzyte (Pewabic quartzyte); N. E. ¼ of sec. 29, T. 65–4, Chub lake. Same as No. 1340 (N. H. W.). P. 199.

44. Magnetic iron ore from the pit at Chub lake, N. E. ¼ of Sec. 29, T. 65–4. P. 160.

45. Quartzyte core from drill; Chub lake, N. E. ¼ of sec. 29, T. 65–4. P. 160.

46. Syenitic gneiss from the north side of Blackfly bay, Gunflint lake. Same as No. 1316 (N. H. W.). P. 199.

47. Gray, red-weathering schist, north shore of Gunflint lake; section III. P. 157.

48. Black flinty slate, north of Gunflint lake; section III. P. 157.

49. Sericitic schist, north of Gunflint lake; section III. P. 157.

50. Gabbro, north of Gunflint lake; section III. P. 157.

51. Hornblende-feldspar schist, north of Gunflint lake; section III. P. 158.

52. Hornblende schist, north of Gunflint lake; section III. P. 158.

53. Mica-schist, north of Gunflint lake; section III. P. 158.

54. Hornblende schist, north of Gunflint lake; section III. P. 158.

55. Very coarsely-crystalline hornblende schist, north of Gunflint lake; section III. P. 158.

56. Same as 55, north of Gunflint lake; section III. P. 158.

57. Reddish syenite, north of Gunflint lake; section III. P. 158.

58. Syenitic gneiss, north of Gunflint lake; section III. P. 158.

58A. Same as 58, but showing the gneissic structure better; north of Gunflint lake; section III. P. 158.

59. Syenitic gneiss, north of Gunflint lake; section III. P. 158.

60. Fine-grained trap, from the west side of the narrows of Gunflint lake; S. E. ¼ of N. W. ¼ sec. 19, T. 65–3. Same as No. 1312 (N. H. W.). P. 199.

61. Diabase from dike in syenite, first falls of Gunflint river north of Gunflint lake. Same as No. 1318 (N. H. W.). P. 160.

61A. Fine condition of No. 61. P. 160.

62. Syenitic gneiss, first falls of Gunflint river north of Gunflint lake. P. 160.

63. A condition of No. 61. P. 161.

64. A condition of No. 61, showing pitted surface. P. 161.

65. Hornblende schist in No. 62; first falls of Gunflint river north of Gunflint lake. P. 161.

66. Conglomeritic syenite from Saganaga lake. P. 200.

67. Syenite, Saganaga lake. P. 200.

68. Black slate, mouth of Ogishke-Muncie creek, N. E. ¼ of S. E. ¼ sec. 26, T. 65–6; Ogishke-Muncie lake. Same as No. 1074 (N. H. W.). P. 197.

68A. Broken condition of No. 68. P. 197.

68B. Portion of No. 68 included in No. 69. P. 197.

68C. Showing conchoidal fracture of No. 68. P. 197.

69. Coarse-jointed massive rock, apparently igneous, mouth of Ogishke-Muncie creek, N. E. ¼ of S. E. ¼ sec. 26, T. 65–6; Ogishke-Muncie lake. Same as No. 1073 (N. H. W.). P. 197.

70. Doleryte, about a quarter of a mile southeast from the shore of Ogishke-Muncie lake; N. E. ¼ of sec. 24, T. 65–6. Same as No. 1068 (N. H. W.). P. 196.

71. Calcite from veins in No. 70.

72. "Marble" from east side of Ogishke-Muncie lake; N. E. ¼ of sec. 24, T. 65–6. Same as No. 1371 (N. H. W.). P. 199.

73. Softer and more schistose portion of No. 72. P. 199.

74. Angular siliceous pieces in No 72. P. 199.

75. Portion of No. 72 showing a soft greenish mineral.

76. Gray quartzyte, S. E. ¼ of N. E. ¼ sec. 24, T. 65–6; Ogishke-Muncie lake. P. 161.

77. Black slate, S. E. ¼ of N. E. ¼ sec. 24, T. 65–6; Ogishke-Muncie lake. P. 161.

78. Siliceous band in No. 76. P. 162.

79. Transition rock from No. 78 to No. 82. P. 162.

80. Transition rock from No. 78 to No. 82. P. 162.

81. Transition rock from No. 78 to No. 82. P. 162.

82. Rock composed mostly of calcareous or dolomitic matter; S. E. ¼ of N. E. ¼ sec. 24, T. 65–6; Ogishke-Muncie lake. P. 162.

83. Part of Ogishke-Muncie conglomerate; S. E. ¼ of N. E. ¼ sec. 24, T. 65–6; Ogishke-Muncie lake. P. 162.

84. Matrix of Ogishke-Muncie conglomerate; from Camper's island, S. E. ¼ of S. W. ¼ sec. 23, T. 65–6; Ogishke-Muncie lake. Same as No. 744 (N. H. W.). P. 194.

85. Gneissic (syenitic?) rock, south shore of the little bay at the southeast corner of Kekequabic lake; S. E. ¼ of S. W. ¼ sec. 2, T. 64–7. Same as No. 1044 (N. H. W.). P. 196.

86. Gray porphyritic rock, from the point which has the corners of secs. 29, 30, 31, and 32, T. 65–6; Kekequabic lake. Same as No. 1094 (N. H. W.). P. 197.

87. Biotite gabbro, N. E. ¼ of S. E. ¼ sec. 4, T. 64–7; Kekequabic lake. Same as 1049 (N. H. W.). P. 196.

88. Gray earthy slate, N. E. ¼ of S. E. ¼ sec. 4, T. 64–7; Kekequabic lake. P. 196.

89. Transition from the slate (No. 88) to the gabbro (No. 87). P. 196.

90. Transition from the slate (No. 88) to the gabbro (No. 87). P. 196.

91. Fine-grained gabbro, from the top of the bluff from which No. 87 was taken; N. E. ¼ of S. E. ¼ sec. 4, T. 64–7; Kekequabic lake. Same as No. 1050 (N. H. W.). P. 196.

92. Chlorite schist, N. W. ¼ of N. E. ¼ sec. 36, T. 65–7; Kekequabic lake. Same as No. 1409 (N. H. W.). P. 168.

93. Reddish syenite, from an island in Kekequabic lake; S. E. ¼ of N. W. ¼ sec. 3, T. 64–7. Same as No. 1100 (N. H. W.). P. 197.

94. A condition of the green chlorite schist, from island in the S. W. ¼ of N. W. ¼ sec. 3, T. 64–7; Kekequabic lake. P. 197.

95. Feldspar porphyry, from an island just northeast of the last; S. W. ¼ of N. W. ¼ sec. 3, T. 64–7; Kekequabic lake. P. 198.

96. Conglomeritic chlorite schist, from the north shore of Kekequabic lake where it is crossed by the line between T. 65–6 and T. 65–7. Same as No. 1098 (N. H. W.). P. 197.

97. Hornblende porphyry, from the north shore of Kekequabic lake; N. E. ¼ of sec. 36, T. 65–7. Same as No. 1059 (N. H. W.). P. 196.

98. Gray siliceous slate, from Knife lake; E. ½ of N. E. ¼ sec. 28, T. 65–7. Same as No. 1428 (N. H. W.). P. 200.

99. Micaceo-syenitic gneiss, from Opinin island, Basswood lake; sec. 10, T. 64–10. Same as No. 1436 (N. H. W.). P. 200.

100. Felsitic schist, from the south end of the portage from Fall lake to Newton lake; S. W. ¼ of sec. 3, T. 63–11. Same as No. 1109 (N. H. W.). P. 198.

101. Fine grained, slightly micaceous, quartzose rock; south shore of Kawishiwi river; N. W. ¼ of N. W. ¼ sec. 27, T. 63–10. Same as No. 989 (N. H. W.). P. 195.

102. Gray, red-weathering, gneissic rock, from an island in the N. W. ¼ of N. W. ¼ sec. 27, T. 63–10; Kawishiwi river. Same as No. 991 (N. H. W.). P. 195.

103. Hornblendic band in No. 102. P. 195.

104. Hornblendic band in No. 102. P. 195.

105. Reddish chloritic rock, N. E. ¼ of N. W. ¼ sec. 27, T. 63–10; south shore of Kawishiwi river. P. 195.

106. Hornblendic gneiss, N. E. ¼ of sec. 27, T. 63–10; south shore of Kawishiwi river. P. 195.

107. Reddish chloritic syenite, N. E. ¼ of N. W. ¼ sec. 27, T.

63–10; south shore of Kawishiwi river. Same as No. 994 (N. H. W.). P. 195.

108. Quartzose schist, grading into No. 105; same locality. P. 195.

109. Quartzose schist, with some biotite; same locality. P. 196.

110. Chloritic schist in No. 105; same locality. P. 196.

111. Fine syenite, from the "Palisades;" N. W. ¼ of S.W. ¼ sec. 4, T. 62–10. Same as No. 979 (N. H. W.). P. 195.

112. Fine grayish syenite, a condition of No. 111; same locality. P. 195.

113. Fine reddish syenite, a condition of 111; same locality. P. 195.

114. Coarse gabbro, east side of Birch lake, N. W. ¼ of sec. 17, T. 61–11. Same as No. 954 (N. H. W.). P. 194.

115. Magnetitic quartzyte, S. W. ¼ of sec. 9, T. 60–12; south of Birch lake. P. 163.

116. Magnetitic quartzyte, N. W. ¼ of sec. 10, T. 60–12; south of Birch lake. P. 163.

117. Biotitic gabbro, S. W. ¼ of sec. 10, T. 60–12; south of Birch lake. P. 162.

118. Same as No. 117, but showing dark bands. Same locality. P. 162.

118A. Same as 118, but from a loose piece. P. 162.

119. Gabbro, N. ½ of sec. 15, T. 60–12; south of Birch lake. P. 162.

120. Gabbro, N. E. ¼ of sec. 15, T. 60–12; south of Birch lake. P. 163.

121. Breccia of mica-schist cemented by granite, from the little point in the N. E. ¼ of S. E. ¼ sec. 21, T. 61–12; Birch lake. Same as No. 958 (N. H. W.). P. 195.

122. Fine-grained gabbro, from the west side of the little bay in the S. E. ¼ of S. W. ¼ sec. 24, T. 62–12; Birch lake. Same as No. 1137 (N. H. W.). P. 198.

123. Fine-grained red syenite, from the S. W. ¼ of S. W. ¼ sec. 24, T. 61–12; just east of the line between secs. 23 and 24, and 300 feet north from the shore of Birch lake. Same as No. 963 (N. H. W.). P. 195.

124. Biotite hornblende schist, N. W. ¼ of S. E. ¼ sec. 12, T. 62–12; east side of White Iron lake. Same as No. 1134 (N. H. W.). P. 198.

125. Biotite hornblende schist, N. W. ¼ of S. E. ¼ sec. 12, T. 62–12; east side of White Iron lake; 70 yards west of No. 124. P. 198.

126. Granite cutting No. 125; same locality. P. 198.

127. Black hornblende gneiss, just south of the line between secs. 6 and 7, T. 62–11; east shore of White Iron lake. This specimen shows the contact between the syenite and hornblende gneiss. Same as No. 1132 (N. H. W.). P. 198.

128. Siliceous schist, from "Silver City;" N. E. ¼ of sec. 32, T. 63–11. Same as No. 950 (N. H. W.). P. 194.

129. Biotitic diabase (?) cut by intrusive syenite, N. W. ¼ of S. E. ¼ sec. 6, T. 62–11, White Iron lake. Same as No. 1128 (N. H. W.). P. 198.

130. Syenite cutting No. 129; same locality. Same as No. 1129 (N. H. W.). P. 198.

131. Syenite taken from a dike in No. 129; same locality. P. 198.

132. Gabbro, north side of the little bay in the S. W. ¼ of S. E. ¼ sec. 15, T. 63–9; Kawishiwi river. P. 163.

133. Magnetitic iron ore in the gabbro, S. E. ¼ of sec. 15, T. 63–9. P. 163.

134. Muscovado, S. E. ¼ of N. E. ¼ sec. 15, T. 63–9; 60 yards northwest of the quarter post between secs. 14 and 15. P. 163.

135. Magnetitic iron ore; same locality as No. 134. P. 163.

136. Gabbro, showing gneissic structure; N. W. ¼ of sec. 5, T. 61–9; hill on east bank of stream. P. 164.

137. Gabbro, showing banding in No. 138; S. W. ¼ of sec. 5, T. 61–9; hill on west bank of stream. P. 165.

138. Gabbro, from same locality as No. 137. P. 165.

139. Red syenitic gneiss; S. ½ of sec. 32, T. 63–10; from a small island near the southern shore of the lake. P. 165.

140. Red syenite; S. ½ of sec. 32, T. 63–10; from a small island just north of the island where No. 139 was found. P. 165.

141. Syenite, with large crystals of hornblende; west side of the little bay in the N. W. ¼ of N. W. ¼ sec. 32, T. 63–10. P. 165.

142. Light gray gneiss; at the portage in the N. E. ¼ of N. W. ¼ sec 31, T. 63–10. P. 165.

143. Hornblende schist(?) in No. 142; same locality. P. 165.

144. Dark hornblende rock, from the southern shore of the lake; S. ½ of sec. 32, T. 63–10. P. 166.

145. Transition from No. 144 to the syenite like No. 140; same locality as No. 144. P. 166.

146. To illustrate the same transition as No. 145; same locality. P. 166.

147. Coarse gabbro; west side of the little bay in the S. W. ¼ of N. W. ¼ sec. 35, T. 62–8; lake Isabelle. P. 166.

148. Granulyte vein in the gabbro; a few rods north of No. 147. P. 166.

149. Very coarse gabbro; from cliff on the west side of the larger bay in the N. W. ¼ of sec. 35, T. 62–8; lake Isabelle. P. 166.

150. Trap rock, S. W. ¼ of N. E. ¼ sec. 35, T. 62–8; lake Isabelle. P. 166.

151. Coarser condition of No. 150; same locality. P. 166.

152. Coarser decayed condition of No. 150; same locality, but a few rods back from the shore. P. 166.

153. Coarser condition of No. 150; same locality as No. 152. P. 166.

154. Condition of No. 150, containing patches of biotite; on the shore, a little north of No. 150. P. 166.

155. A decayed condition of No. 154; same locality. P. 166.

156. A coarser condition of No. 154 and No. 155; same locality. P. 166.

157. Same trap, near contact with the gabbro; N. ½ of N. E. ¼ sec. 35, T. 62-8, lake Isabelle; on the shore, a few steps north of No. 156. P. 167.

158. Fine diabase from dike, N. E. ¼ of N. E. ¼ sec. 35, T. 62–8; lake Isabelle. P. 167.

159. Diabase from dike, S. W. ¼ of sec. 30, T. 62–7; lake Isabelle. P. 167.

160. Finer diabase from edge of the same dike from which No. 159 was taken. P. 167.

161. Fine diabase from dike, W. ½ of sec. 31, T. 62–7; lake Isabelle. P. 167.

162. Very coarse gabbro, north shore of Bellissima lake; probably from sec. 27, T. 61–7. P. 167.

163. Gray feldspathic rock, S. W. ¼ of sec. 21, T. 60–6; Pine lake. P. 163.

163A. Portion of No. 163 showing dark siliceous fragment; same locality as No. 163. P. 168.

163B. Transition from No. 163 to No. 164; same locality. P. 168.

164. Granulyte, S. W. ¼ of sec. 21, T. 60–6; Pine lake. P. 168.

164A. A darker and more siliceous condition of No. 164; same locality. P. 168.

165. Fine trap, S. W. ¼ of sec. 21, T. 60–6; Pine lake. P. 168.

165A. No. 165 containing fragments of No. 164; same locality. P. 168.

165B. A condition of No. 155 A; same locality. P. 168.

166. Diabasic rock, N. W. ¼ of sec. 28, T. 60–6; Pine lake. P. 168.

167. Diabasic rock, west shore of Pine lake; T. 60–6. P. 168.

168. Very fine diabasic rock, west shore of Pine lake; T. 60–6. P. 168.

169. Very fine diabasic rock, west shore of Pine lake; T. 60–6. P. 168.

170. Micaceous schist, from the syenite; north of Gunflint lake. P. 158.

171. Hornblendic schist, from the syenite; north of Gunflint lake. P. 158.

172. Coarse hornblendic schist, from the syenite; north of Gunflint lake. P. 158.

173. Syenite holding hornblendic schist fragments; north of Gunflint lake. P. 159.

174. Synenitic gneiss, north of Gunflint lake. P. 159.

175. Gabbro, S. W. ¼ of S. E. ¼ sec. 36, T. 65–3; south shore of Mayhew lake. P. 169.

176. Lighter colored gabbro, from end of little point in the S. W. ¼ of S. E. ¼ sec. 36, T. 65–3; Mayhew lake. P. 169.

177. Magnetic iron ore in the gabbro; same locality as No. 176. P. 169.

178. Decayed gabbro; on the line between ranges 2 and 3, just south of Mayhew lake. P. 169.

179. Magnetic iron ore in the gabbro, from the point crossed by the line between secs. 31 and 32, T. 65–2; Iron lake. P. 170.

180. Magnetitic gabbro; same locality as No. 179. P. 170.

181. Fine muscovado-like rock, S. E. ¼ of N. W. ¼ sec. 4, T. 64–2; Portage lake. P. 170.

182. Gabbro, from the little point in the N. W. ¼ of N. E. ¼ of N. W. ¼ sec. 12, T. 64–2; Poplar lake. P. 171.

183. Very fine gabbro, a condition of No. 182; same locality. P. 171.

184. Light gray gabbro with the labradorite collected together in spots; S. E. ¼ of N. E. ¼ sec. 12, T. 64–2; Poplar lake. P. 171.

185. Gabbro, from hill a quarter of a mile north of Meeds' lake, and a little west of the centre of sec. 15, T. 64–2. P. 172.

186. Rough Animike slate, N. W. ¼ of N. E. ¼ sec. 14, T. 64–2; Meeds' lake. P. 172.

187. Gabbro, S. E. ¼ of S. E. ¼ sec. 29, T. 64–2; north shore of Winchell lake. P. 174.

188. Goarse gabbro, from the point crossed by the line between secs. 31 and 32, T. 62–4; south shore of Winchell lake. P. 174.

189. Gabbro, from the bluff in the N. W. ¼ of N. W. ¼ sec. 31, T. 64–2; south shore of Winchell lake. P. 174.

190. Gabbro holding some pinkish feldspar, 20 feet above No. 189. P. 174.

191. Altered gabbro, reddish; ten feet above No. 190. P. 175.

192. Very dark syenite, two feet above No. 191. P. 175.

193. Very dark syenite, two feet above No. 191. P. 175.

194. Fine pinkish-gray syenite, just above No. 193. P. 175.

195. Pinkish-gray syenite, just above No. 194. P. 175.

196. Pinkish-gray syenite, from top of bluff; same locality. P. 175.

197. Showing change from gabbro to syenite; same locality. P. 175.

198. A condition of the gabbro, N. W. ¼ of N. W. ¼ sec. 31, T. 64–2; Winchell lake, north end of portage to Sham lake. P. 175.

199. Altered gabbro, S. W. ¼ of N. W. ¼ sec. 31, T. 64–2; north end of Sham lake, at the portage to Winchell lake. P. 176.

200. Fine red syenite, S. W. ¼ of N. W. ¼ sec. 31, T. 64–2; east side of Sham lake. P. 176.

201. Altered gabbro (?), S. E. ¼ of S. E. ¼ sec. 36, T. 64–3; near the southwest corner of Sham lake. P. 176.

202. Fine red syenite, S. E. ¼ of S. W. ¼ sec. 1, T. 63–3; west side of Lost lake. P. 176.

203. Dark siliceous trap, S. E. ¼ of S. W. ¼ sec. 12, T. 63–3, east side of bay; Brulé lake. P 177.

204. A condition of the gabbro (?) a little south of No. 203. P. 177.

205. Gray feldspar porphyry, from the point in the S. E. ¼ of N. E. ¼ of N. W. ¼ sec. 13, T. 63–3; Brulé lake. P. 177.

206. Dark feldspar porphry; same locality as No. 205. P. 177.

207. Red quartz porphyry; a few yards south of the last. P. 178.

207A. A darker and more siliceous condition of No. 207, near the contact with No. 208; same locality. P. 178.

208. Fine diabase, in contact with No. 207; same locality. P. 178.

209. Diabase-like rock, inclined to be amygdaloidal; small island in the S. E. ¼ of S. E. ¼ sec. 18, T. 63–3; Brulé lake. P. 178.

210. Gabbro, S. W. ¼ of sec. 18, T. 63–3; lake Georgia, a short distance west of the portage from Brulé lake. P. 179.

211. Dark feldspar porphyry; lake Georgia, a short distance west of No. 210. P. 179.

212. Trap; near its contact with the gabbro (No. 213); N. E. ¼ of S. W. ¼ sec. 13, T. 63–4; north side of lake Georgia. P. 179.

212A. Coarser condition of No. 212, farther from the contact. P. 179.

213. Gabbro in contact with trap (No. 212); same locality. P. 179.

214. Fine red syenite, S. W. ¼ of sec. 12, T. 63–4; Surveyor's lake, on the portage going west to Found lake. P. 179.

215. Diabase, S. ½ of sec. 11, T. 63–4; hill on north shore of Found lake. P. 180.

216. Fine red syenite holding pieces of a darker rock; S. ½ of sec. 11, T. 63–4; north shore of Found lake. P. 180.

217. Gabbro, S. W. ¼ of N. E. ¼ sec. 11, T. 63–4; lake Ida Belle. P. 180.

218. Diabase, S. W. ¼ of N. W. ¼ sec. 11, T. 63–4,—just east of the line between secs. 10 and 11; lake Ida Belle. P. 180.

219. Fine diabase from dike in gabbro, little point in the S. E. ¼ of sec. 10, T. 63–4; lake Ida Belle. P. 180.

220. Gabbro cut by the above dike. P. 180.

221. Fine-grained rock resembling "muscovado;" N. W. ¼ of sec. 15, T. 63–4, near the line between secs. 10 and 15; southwest of lake Ida Belle. P. 181.

222. Large crystals of hornblende from vein in gabbro; southwest of lake Ida Belle, near the last locality. P. 181.

223. Gabbro rich in magnetite; southwest of lake Ida Belle, near the last locality. P. 181.

224. Magnetite from the gabbro; N. ½ of sec. 16, T. 63–4, near the line between secs. 9 and 16; southwest of lake Ida Belle. P. 181.

225. Fine red syenite, east side of entrance to the small bay in the N. W. ¼ of N. E. ¼ sec. 10, T. 63–4; lake Ida Belle. P. 181.

226. Diabase from dike in gabbro; same locality as No. 225. P. 181.

227. Gabbro; same locality. P. 181.

228. Fine red syenite underlying the gabbro; north side of small island in the N. E. ¼ of S. E. ¼ sec. 3, T. 63–4; lake Ida Belle. P. 182.

229. Dark rock cut by veins of the following; hill in the E. ½ of sec. 3, T. 63–4; lake Ida Belle. P. 182.

230. Fine red syenite from veins in No. 229; same locality. P. 182.

231. Showing contact of Nos. 229 and 230. P. 182.

232. Fine red syenite from vein in gabbro; S. E. ¼ of sec. 35, T. 64–4, lake Ida Belle; on the portage going north. P. 183.

233. A decayed condition of the gabbro; S. E. ¼ of N. E. ¼ sec. 26, T. 64–4; west shore near the north end of Narrow lake. P. 183.

233½. Muscovado, N. E. ¼ sec. 33, T, 65–4; west shore of Draper lake. P. 184.

234. Fine gray syenite underlying the gabbro; probably in the S. W. ¼ of sec. 29, T. 65–4; on the portage from lake No. 3 to lake No. 4. P. 184.

235. Gabbro overlying No. 234; same locality. P. 184.

236. Muscovado; same locality as No. 234. P. 185.

237. Fine gabbro, probably in S. ½ of sec. 29, T. 65–4; from little island in southern part of lake No. 4. P. 185.

238. Magnetic iron ore from the quartzyte, S. E. ¼ of S. E. ¼ sec. 25, T. 65–5; south shore of Flying Cloud lake, near its eastern end. P. 185.

239. Greenstone; same locality as No. 238. P. 185.

240. Magnetic iron ore from the quartzyte; probably in the S. E. ¼ of S. E. ¼ sec. 26, T. 65–5. P. 186.

241. Greenstone, 12 feet north of No. 240. P. 186.

242. Magnetitic quartzyte, just south of No. 241. P. 186.

243. Magnetitic quartzyte lying on No. 244; probably in the N. W. ¼ of N. E. ¼ sec. 35, T. 65–5. P. 186.

244. Greenstone underlying No. 243; same locality. P. 186.

245. Fine gabbro, from the little point in the N. E. ¼ of N. E. ¼ sec. 14, T. 64–7; Shoo-fly lake. P. 186.

246. Gabbro, west side of the small lake in the S. W. ¼ of sec. 13, T. 64–7. P. 187.

247. Decayed condition of No. 246; west shore, near the south end of the small lake in the S. W. ¼ of sec. 13, T. 64–7. P. 187.

248. Olivinitic iron ore, S. E. ¼ of S. W. ¼ sec. 14, T. 64–7; north side of Fraser lake. P. 187.

249. Coarse hornblende (?) rock; same locality. P. 187.

250. Olivinitic iron ore in No. 249; same locality. P. 187.

251. Magnetitic quartzyte in No. 249; same locality. P. 187.

252. Olivinitic iron ore; same locality. P. 187.

253. Coarse hornblende (?) rock, not as much decayed as No. 249; same locality. P. 187.

254. Muscovado; same locality. P. 187.

255. No. 249 containing considerable magnetite; same locality. P. 187.

256. Same as No. 255 and showing a piece of No. 254; same locality. P. 187.

257. Muscovado from northern foot of the ridge; same locality. P. 188.

258. Magnetitic quartzyte; same locality. P. 188.

259. Magnetitic quartzyte showing banding; same locality. P. 188.

260. Showing contact of the quartzyte and the hornblende rock (No. 249); same locality. P. 188.

261. Fine decayed gabbro, N. W. ¼ of N. E. ¼ sec. 23, T. 64–7; north shore of Fraser lake. P. 188.

262. Olivintic iron ore; same locality. P. 188.

263. Magnetitic quartzyte; same locality. P. 188.

264. Magnetitic quartzyte, showing banding; same locality. P. 188.

265. Band of magnetite from the quartzyte; same locality. P. 188.

266. Muscovado-like rock, from a bed in the quartzyte; same locality. P. 188.

267. Olivinitic iron ore; same locality. P. 189.

268. Large crystals, apparently similar to No. 249, but containing much magnetite; same locality. P. 188.

269. Gabbro, N. E. ¼ of sec. 28, T. 64–7; a quarter of a mile north of Thomas lake. P. 189.

270. Muscovado holding irregular blotches of a light colored feldspar; W. ½ of sec. 27, T. 64–7; north shore of Thomas lake. P. 189.

271. Hornblende (?) rock similar to Nos. 249 and 253, N. E. ¼ of sec. 29, T. 64–7; north shore of Thomas lake. P. 189.

272. Magnetitic quartzyte showing banding on weathered surface; same locality. P. 189.

273. Iron ore, apparently almost pure magnetite; same locality. P. 189.

274. Magnetitic quartzyte; same locality. P. 190.

275. Same as No. 274. P. 190.

276. Pink gabbro holding small quantities of what appears to be a red oxide of iron; east side of the long bay in sec. 15, T. 63–7; lake Alice. P. 191.

277. Gabbro, S. E. ¼ of N. W. ¼ sec. 15, T. 63–7; east shore of lake Alice. P. 191.

278. Green chloritic schist; north of Cady house, Tower. Same as No. 868 (N. H. W.). P. 194.

279. Rough, scarcely banded jasper; 25 feet below the surface; Stone mine, Tower. Same as No. 892 (N. H. W.). P. 194.

280. Red jasper with darker bands of iron ore; Stone mine, Tower. Same as No. 903 (N. H. W.). P. 194.

281. Matrix of conglomerate occurring north of the Cady house, Tower. Same as No. 908 (N. H. W.). P. 194.

282. Breccia, now converted to hematite and a floury white mineral; Breitung mine, Tower. Same as No. 916 (N. H. W.). P. 194.

283. Black or purplish-black clay slate; south shore of Pine island, Vermilion lake; a few feet east of the line between ranges 15 and 16. Same as No. 921 (N. H. W.). P. 194.

284. Sericitic schist, rather siliceous; north shore of Pine island, Vermilion lake; on the line between ranges 15 and 16. P. 192.

285. Sericitic schist; Pine island. P. 192.

286. Green, somewhat sericitic schist; Pine island. P. 192.

287. Green, somewhat graywacke-like rock; Pine island. P. 192.

288. Rough sericitic schist; Pine island. P. 192.

289. Green, somewhat chloritic (?) schist; Pine island. P. 192.

290. Light gray argillaceous slate; Pine island. P. 192.

291. Coarser and rather sericitic condition of No. 290; Pine island. P. 192.

292. Coarser and rather sericitic condition of No. 290; Pine island. P. 192.

293. Coarser and rather sericitic condition of No. 290; Pine island. P. 192.

294. Light gray argillaceous slate; Pine island. P. 192.

295. Gray argillaceous slate; Pine island. P. 192.

296. A more siliceous condition of the slate; Pine island. P. 192.

297. Gray argillaceous slate; Pine island. P. 192.

298. Argillaceous slate showing both the gray and black bands; south shore of Pine island, on the line between ranges 15 and 16. P. 192.

V.

MUSEUM ADDITIONS.

SPECIMENS REGISTERED IN THE GENERAL MUSEUM IN 1887–88.

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of Specimen.	Locality.	Formation.	Collector and Remarks.
6191	Jan., 1886	Geol. Survey	Gravel, largely limestone	Indef.	Albert Lea, Minn.	Drillings from the well at Albert Lea	From Mayor A. C. Wedge, 80 feet.
6192	Jan., 1886	Geol. Survey	Sand and gravel	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 95 feet.
6193	Jan., 1886	Geol. Survey	Sand, mainly quartz	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 105 feet.
6194	Jan., 1886	Geol. Survey	Gravel and sand	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 112 feet.
6195	Jan., 1886	Geol. Survey	Sand	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 113 feet.
6196	Jan., 1886	Geol. Survey	Sand with magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 114 feet.
6197	Jan., 1886	Geol. Survey	Magnesian limestone and sand	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 115 feet.
6198	Jan., 1886	Geol. Survey	Magnesian limestone and sand	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 115 feet.
6199	Jan., 1886	Geol. Survey	Sand with some limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 130 feet.
6200	Jan., 1886	Geol. Survey	Magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 143 feet.
6201	Jan., 1886	Geol. Survey	Light-gray shale	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 155 feet.
6202	Jan., 1886	Geol. Survey	Light-gray shale	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 160 feet.
6203	Jan., 1886	Geol. Survey	Battered films of metalic iron	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 165 feet.
6204	Jan., 1886	Geol. Survey	Gray shale, sandy	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 172 feet.
6205	Jan., 1886	Geol. Survey	Gray shale	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 210 feet.
6206	Jan., 1886	Geol. Survey	Gray shale	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 213 feet.
6207	Jan., 1886	Geol. Survey	Calcareous shale	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 220 feet.
6208	Jan., 1886	Geol. Survey	Compact, light-colored limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 230 feet.
6209	Jan., 1886	Geol. Survey	Mainly magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 234 feet.
6210	Jan., 1886	Geol. Survey	Mainly white quartz sand	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 236 feet.
6211	Jan., 1886	Geol. Survey	Mainly white quartz sand	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 237 feet.
6212	Jan., 1886	Geol. Survey	Mainly white quartz sand	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 240 feet.
6213	Jan., 1886	Geol. Survey	Buff magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 241 feet.
6214	Jan., 1886	Geol. Survey	Buff magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 243 feet.
6215	Jan., 1886	Geol. Survey	Reddish-buff magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 245 feet.
6216	Jan., 1889	Geol. Survey	Reddish-buff magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 250 feet.
6217	Jan., 1886	Geol. Survey	Reddish buff magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 254 feet.
6218	Jan., 1886	Geol. Survey	Reddish-buff magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 258 feet.
6219	Jan., 1886	Geol. Survey	Reddish-buff magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 260 feet.
6220	Jan., 1886	Geol. Survey	Reddish-buff magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 265 feet.
6221	Jan., 1886	Geol. Survey	Reddish-buff magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 270 feet.
6222	Jan., 1866	Geol. Survey	Light-gray, cryst. magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 275 feet.
6223	Jan., 1886	Geol. Survey	Buff magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 285 feet.
6224	Jan., 1886	Geol. Survey	Light-buff magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 295 feet.
6225	Jan., 1886	Geol. Survey	Vesicular, buff magnesian limestone	Indef.	Albert Lea, Minn.		From Mayor A. C. Wedge, 300 feet.
6226	Oct., 1885	Geol. Survey	Drillings, mixed, mainly quartzose sand	Indef.	4 ms. S.E. f. New Ulm.	Cret.	From C. M Phelps.
6227	Feb., 1886	Presented	Fibrous gypsum	2	Camillus, N. Y.		From N. H. Winchell.

6228	Feb., 1886	Presented	Gypsum	1	Camillus, N. Y.		From N. H. Winchell.
6229	Feb., 1886	Presented	Gypsum	1	Sandusky, Ohio		From N. H. Winchell.
6230	Feb., 1886	Presented	Gypsum	2	Ottawa Co., Ohio		From N. H. Winchell.
6231	Feb., 1886	Presented	Fibrous gypsum	2	Grand Rapids, Mich		From N. H. Winchell.
6232	Feb., 1886	Presented	Wollastonite	1	Rock Harbor, I. Royale		From N. H. Winchell.
6233	Feb., 1886	Presented	Tufa	2	Marcellus Falls, N. Y.		From N. H. Winchell.
6234	Feb., 1886	Presented	Calcite	7			From N. H. Winchell.
6235	Feb., 1886	Presented	Chlorastrolites in rock	1	RockHarbor, I. Royale		From N. H. Winchell.
6236	Feb., 1886	Presented	Niagara limestone	1	Joliet, Ill		From N. H. Winchell.
6237	Feb., 1886	Presented	Feldspathic quartzyte	1	Ann Arbor, Mich		From N. H. Winchell.
6238	Feb., 1886	Presented	Aphanite	1	Ann Arbor, Mich		From N. H. Winchell.
6239	Feb., 1886	Presented	Gneiss	1	Ann Arbor, Mich		From N. H. Winchell.
6240	Feb., 1886	Presented	Gneiss	1	Ann Arbor, Mich		From N. H. Winchell.
6241	Feb., 1886	Presented	Feldspathic quartzyte	1	Ann Arbor, Mich		From N. H. Winchell.
6242	Feb., 1886	Presented	Mottled marble	1	Ann Arbor, Mich		From N. H. Winchell.
6243	Feb., 1886	Presented	Buhr stone	1	Ohio		From N. H. Winchell.
6244	Feb., 1886	Presented	Celestite	Indef	Pt. aux Peaux		From N. H. Winchell.
6245	Feb., 1886	Presented	Drillings, sand, 20 feet	Indef.	Gibbon, Sibley Co.		From Andrew Erickson. } Under 275 ft. blue clay.
6246	Feb., 1886	Presented	Drillings, remains of wood, fr. No. 6245	Indef.	Gibbon, Sibley Co.		From Andrew Erickson.
6247	Feb., 1886	Presented	Drillings, red granite, 30 ft.	Indef.	Gibbon, Sibley Co.		From Andrew Erickson.
6248	1878.	Geol. Survey.	Catlinite with glacial markings	1	Pipestone Co.	Potsdam	From N. H. Winchell.
6249	March, 1886	Presented	Silver ore (pulverized)	1	Newburyport, Mass		From G. R. Lumsden, Orig. No. 1.
6250	March, 1886	Presented	Quartz crystals	Indef.	N. Stonington, Conn		From G. R. Lumsden, Orig. No. 2.
6251	March, 1886	Presented	Sillimanite and zircon w. crys. of monosite	Indef.	Norwich Falls, Conn		From G. R. Lumsden, Orig. No. 3.
6252	March, 1886	Presented	Prehnite	1	Hartford, Conn		From G. R. Lumsden, Orig. No. 4.
6253	March, 1886	Presented	Asbestos	1	New Haven, Conn		From G. R. Lumsden, Orig. No. 5.
6254	March, 1886	Presented	Amethyst	1	Nova Scotia		From G. R. Lumsden, Orig. No. 6.
6255	March, 1886	Presented	Brucite and chondrodite	1	Hoboken, N. J.		From G. R. Lumsden, Orig. No. 7.
6256	March, 1886	Presented	Magnetic iron ore	1	New Jersey		From G. R. Lumsden, Orig. No. 8.
6257	March, 1886	Presented	Micaceous iron ore	1	Africa		From G. R. Lumsden, Orig. No. 151.
6258	March, 1886	Presented	Enstatite	1	Chester Co., Pa.		From G. R. Lumsden, Orig. No. 11.
6259	March, 1886	Presented	Moss Agate	1	Cupar, Scotland		From G. R. Lumsden, Orig. No. 12.
6260	March, 1886	Presented	Prismatic talc mica	1	Greiner, Tyrol		From G. R. Lumsden, Orig. No. 18.
6261	March, 1886	Presented	Iron mica	1	Löwenberg, Ger		From G. R. Lumsden, Orig. No. 20.
6262	March, 1886	Presented	Rhomboidal graphite	1	Altstadt, Ger		From G. R. Lumsden, Orig. No. 21.
6263	March, 1886	Presented	Glassy actinolite	1	Zoeptau, Ger		From G. R. Lumsden, Orig. No. 25.
6264	March, 1886	Presented	Quartz crystals	1	New Haven, Conn		From G. R. Lumsden, Orig. No. 26.
6265	March, 1886	Presented	Basaltic hornblende	1	Schima, Bohemia		From G. R. Lumsden, Orig. No. 26.
6266	March, 1886	Presented	Selenite	3	Colorado		From G. R. Lumsden, Orig. No. 27.
6267	March, 1886	Presented	Paraffin, from coal	1			From G. R. Lumsden, Orig. No. 30.
6268	March, 1886	Presented	Tremolite	1	Tyrol		From G. R. Lumsden, Orig. No. 29.
6269	March, 1886	Presented	Augite	7	Schima, Bohemia		From G. R. Lumsden, Orig. No. 31.
6270	March, 1886	Presented	Schiller spar	1	Volpersdorf		From G. R. Lumsden, Orig. No. 32.
6271	March, 1886	Presented	Plumbago	1	PrestonConn		From G. R. Lumsden, Orig. No. 33.
6272	March, 1886	Presented	Moss Agate	1	Sweet-water Co, Wyo		From G. R. Lumsden, Orig. No. 34.
6273	March, 1886	Presented	Prismatic Topaz	Indef.	Schneckenstein, Ger		From G. R. Lumsden, Orig. No. 35.
6274	March, 1886	Presented	Agate	1	Texas		From G. R. Lumsden, Orig. No. 36.
6275	March, 1886	Presented	Zircon	1	Brewig, Norway		From G. R. Lumsden, Orig. No. 37.

Specimens Registered in the General Museum in 1887–88.—(*Continued.*)

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of Specimen	Locality.	Formation.	Collector and Remarks.
6276	March, 1886	Presented	Garnet sand	Indef	Roxbury, Mass		From G. R. Lumsden, Orig. No. 38.
6277	March, 1886	Presented	Iolite	1	Origarfvi, Finland		From G. R. Lumsden, Orig. No. 39.
6278	March, 1886	Presented	Erlane (Breithauptite)	1	Schwarzenberg, Ger.		From G. R. Lumsden, Orig. No. 41.
6279	March, 1886	Presented	Galena	Indef	Dubuque, Iowa		From G. R. Lumsden, Orig. No. 42.
6280	March, 1886	Presented	Asbestos	1	Toronto, Canada		From G. R. Lumsden, Orig. No. 43.
6281	March, 1886	Presented	Garnets	5	Haddam, Conn		From G. R. Lumsden, Orig. No. 44.
6282	March, 1886	Presented	Green Feldspar	4	Rockport, Mass		From G. R. Lumsden, Orig. No. 50.
6283	March, 1886	Presented	Lead Selenate	1	Durrenberg, Germ		From G. R. Lumsden, Orig. No. 51.
6284	March, 1886	Presented	Mica	1	New Haven, Conn		From G. R. Lumsden, Orig. No. 52.
6285	March, 1886	Presented	Asbestos	1	Norwalk, Conn		From G. B Lumsden, Orig. No. 53.
6286	March, 1886	Presented	Cyanite	1	Greiner, Tyrol		From G. R. Lumsden, Orig. No. 54.
6287	March, 1886	Presented	Asbestos	1	Vermont		From G. R. Lumsden, Orig. No. 55.
6288	March, 1886	Presented	Sodalite	1	Eifel, Germ		From G. R. Lumsden, Orig. No. 56.
6289	March, 1886	Presented	Hayanite	1	Laacher, Germ		From G. R. Lumsden, Orig. No. 57.
6290	March, 1886	Presented	Epidote	2	Franconia, N. H		From G. R. Lumsden, Orig. No. 59.
6291	March, 1886	Presented	Spodumene	1	Sterling, Mass		From G. R. Lumsden, Orig. No. 60.
6292	March, 1886	Presented	Cobalt	3			From G. R. Lumsden, Orig. No. 62.
6293	March, 1886	Presented	Chiastolite	1	Gefrees, Germ		From G. R. Lumsden, Orig. No. 63.
6294	March, 1886	Presented	Porcelainyte	1	Toeplitz, Germ		From G. R. Lumsden, Orig. No. 65.
6295	March, 1886	Presented	Asbestos	Indef	York Co., Pa		From G. R. Lumsden, Orig. No. 68.
6296	March, 1886	Presented	Tripolyte	1	Bilin, Prussia		From G. R. Lumsden, Orig. No. 69.
6297	March, 1886	Presented	Magnetite	1	Rhode Island		From G. R. Lumsden, Orig. No. 74.
6298	March, 1886	Presented	Graphite	1	Ticonderoga, N. Y		From G. R. Lumsden, Orig. No. 76.
6299	March, 1886	Presented	Stibnite	1	Halbermond		From G. R. Lumsden, Orig. No. 77.
6300	March, 1886	Presented	Onyx	1	Oberstein, Germ		From G. R. Lumsden, Orig. No. 78.
6301	March, 1886	Presented	Chloropal	Indef	Madura, India		From G. R. Lumsden, Orig. No. 79.
6302	March, 1886	Presented	Calamine	1	Wiesloch		From G. R. Lumsden, Orig. No. 80.
6303	March, 1886	Presented	Calamine	1	Raibel, Corinthia		From G. R. Lumsden, Orig. No. 82.
6304	March, 1886	Presented	Black mica schist	1	Ames, N. Y		From G. R. Lumsden, Orig. No. 85.
6305	March, 1886	Presented	Wolframite	1	Zirmwald, Bohemia		From G. R. Lumsden, Orig. No. 87.
6306	March, 1886	Presented	Covellite	1	Pennsylvania		From G. R. Lumsden, Orig. No. 88.
6307	March, 1886	Presented	Iron pyrites	1	Marienberg, Germ		From G. R. Lumsden, Orig. No. 93.
6308	March, 1886	Presented	Hexahedral iron pyrites	1	Alsan, Germ		From G. R. Lumsden, Orig. No. 94.
6309	March, 1886	Presented	Iron and shale	1	York Common, N. Y.		From G. R. Lumsden, Orig. No. 96.
6310	March, 1886	Presented	Petrified cottonwood	1	Colorado		From G. R. Lumsden, Orig. No. 97.
6311	March, 1886	Presented	Hematite	1	Irgang, Bohemia		From G. R. Lumsden, Orig. No. 99.
6312	March, 1886	Presented	Zircon	Indef	Green River, Henderson Co., N. C.		From G. R. Lumsden, Orig. No. 100.

6313	March, 1886	Presented	Ferruginous quartz	1	Schellerhan, Germ	From G. R. Lumsden, Orig. No. 102.
6314	March, 1886	Presented	Tremolite	1		From G. R. Lumsden, Orig. No. 106.
6315	March, 1886	Presented	Pisiform ironstone	Indef.	Schafhausen, Germ	From G. R. Lumsden, Orig. No. 107.
6316	March, 1886	Presented	Magnetite	1	Philipstad, Sweden	From G. R. Lumsden, Orig. No 111.
6317	March, 1886	Presented	Siderite	1	Germany	From G. R. Lumsden, Orig. No. 114.
6318	March, 1886	Presented	Native sulphur	1	Sicily	From G. R. Lumsden, Orig. No. 115.
6319	March, 1886	Presented	Red cobalt ochre	1	Schneeberg, Germ	From G. R. Lumsden, Orig. No. 119.
6320	March, 1886	Presented	Copper nickel	1	Schneeberg, Germ	From G. R. Lumsden, Orig. No. 121.
6321	March, 1886	Presented	Variegated copper	1	Freiberg, Germ	From G. R. Lumsden, Orig. No. 125.
6322	March, 1886	Presented	Copper pyrites	1	Siegen, Germ	From G. R. Lumsden, Orig. No. 126.
6323	March, 1886	Presented	Copper pyrites	1	Alsan, Germ	From G. R. Lumsden, Orig. No. 127.
6324	March, 1886	Presented	Gray copper	1	Thuringia	From G. R. Lumsden, Orig. No. 128.
6325	March, 1886	Presented	Red oxyde of copper	1	Dillenberg, Nassau	From G. R. Lumsden, Orig. No. 131.
6326	March, 1886	Presented	Malachite	1	Dillenberg, Nassau	From G. R. Lumsden, Orig. No. 132.
6327	March, 1886	Presented	Blue copper	1	Rheinbreitenbach	From G. R. Lumsden, Orig. No. 133.
6328	March, 1886	Presented	Iron slag	2	Norwich, Conn	From G. R. Lumsden, Orig. No. 137.
6329	March, 1886	Presented	Hepatic mercurial-ore	1	Iddria, Illyrien	From G. R. Lumsden, Orig. No. 138.
6330	March, 1886	Presented	Argentite	1	Freiberg, Germ	From G. R. Lumsden, Orig. No. 140.
6331	March, 1886	Presented	Williamsite	1	Rock Springs, Ind	From G. R. Lumsden, Orig. No. 142.
6332	March, 1886	Presented	Nagyagite	1	Nagyag, Transsylva'a	From G. R. Lumsden, Orig. No. 143.
6333	March, 1886	Presented	Native platina	Indef.	Tagelsk, Ural	From G. R. Lumsden, Orig. No. 144.
6334	March, 1886	Presented	Silver pyrites	1	Mont. Co., N. Y	From G. R. Lumsden, Orig. No. 145.
6335	March, 1886	Presented	Blue iron earth	Indef.	Ebstorf	From G. R. Lumsden, Orig. No. 152.
6336	March, 1886	Presented	Asbestos	Indef.	Canterbury, N. H	From G. R. Lumsden, Orig. No. 153.
6337	March, 1886	Presented	Beryl	1	Canada	From G. R. Lumsden, Orig. No. 157.
6338	March, 1886	Presented	Mica	1	New Jersey	From G. R. Lumsden, Orig. No. 158.
6339	March, 1886	Presented	Brown chalcedony	1	Madura, India	From G. R. Lumsden, Orig. No. 159.
6340	March, 1886	Presented	Brown coal	1	Bruhl, Germ	From G. R. Lumsden, Orig. No. 160.
6341	March, 1886	Presented	Peat	1	Kloster Laach	From G. R. Lumsden, Orig. No. 162.
6342	March, 1886	Presented	Native boracic acid	Indef.	Vulkano	From G. R. Lumsden, Orig. No. 163.
6343	March, 1886	Presented	Hayesine	Indef.	Iquique, Peru	From G. R. Lumsden, Orig. No. 165.
6344	March, 1886	Presented	Brown coal	1	Frierdorf, Bonn	From G. R. Lumsden, Orig. No. 172.
6345	March, 1886	Presented	Nitratine	Indef.	Chili	From G. R. Lumsden, Orig. No. 176.
6346	March, 1886	Presented	Celestite	Indef.	Dornburg, Jena	From G. R. Lumsden, Orig. No. 179.
6347	March, 1886	Presented	Garnet	1	New Hampshire	From G. R Lumsden, Orig. No. 180.
6348	March, 1886	Presented	Crystals of hematite	1	New York	From G. R. Lumsden, Orig. No. 183.
6349	March, 1886	Presented	Emery	1	Naxos (Grecian Isl.)	From G. R. Lumsden, Orig. No. 186.
6350	March, 1886	Presented	Asbestos	Indef.	Greiner, Tyrol	From G. R. Lumsden, Orig. No. 189.
6351	March, 1886	Presented	Calcite	1	Howe's cave, N. Y	From G. R. Lumsden, Orig. No. 192.
6352	March, 1886	Presented	Native lodestone	1	Mt. Calamite, Elba	From G. R. Lumsden, Orig. No. 195.
6353	March, 1886	Presented	Rutile	5	Freiberg, Germ	From G. R. Lumsden, Orig. No. 195 A.
6354	March, 1886	Presented	Corundum (ruby)	Indef.	Capelan Mts	From G. R. Lumsden, Orig. No. 196.
6355	March, 1886	Presented	Corundum (sapphire)	1	Miark, Germ	From G. R. Lumsden, Orig. No. 197.
6356	March, 1886	Presented	Spinel (blue)	1	Sweden	From G. R. Lumsden, Orig. No. 199.
6357	March, 1886	Presented	Spinel (ruby)	Indef.	Candy, Ceylon Isl	From G. R. Lumsden, Orig. No. 200.
6358	March, 1886	Presented	Tremolite	1	New York	From G. R. Lumsden, Orig. No. 202.
6359	March, 1886	Presented	Beryl	1	Haddam, Conn	From G. R. Lumsden, Orig. No. 204.
6360	March, 1886	Presented	Smoky quartz	1	N. Benton, N. H	From G. R. Lumsden, Orig. No. 208.

Specimens Registered in the General Museum in 1887–88.—(*Continued.*)

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of Specimen.	Locality.	Formation.	Collector and Remarks.
6361	March, 1886	Presented	Tourmaline (red)	1	Moravia		From G. R. Lumsden, Orig. No. 209.
6362	March, 1886	Presented	Smoky quartz	3	St. Gothard		From G. R. Lumsden, Orig. No. 212.
6363	March, 1886	Presented	Amethyst	1	Oberstein		From G. R. Lumsden, Orig. No. 213.
6364	March, 1886	Presented	Cat's-eye	1	Hoff in Bavaria		From G. R. Lumsden, Orig. No. 214.
6365	March, 1886	Presented	Pyrolusite	1	New York		From G. R. Lumsden, Orig. No. 216.
6366	March, 1886	Presented	Carnelian	1	Oberstein		From G. R. Lumsden, Orig. No. 219.
6367	March, 1886	Presented	Andalusite	2	Lancaster, N. H.		From G. R. Lumsden, Orig. No. 223.
6368	March, 1886	Presented	Jasper (globular)	1	Kandern, Baden		From G. R. Lumsden, Orig. No. 224.
6369	March, 1886	Presented	Muscovite	1	New Haven, Conn.		From G. R. Lumsden, Orig. No. 226.
6370	March, 1886	Presented	Bog iron ore	1	Ft. Plain, N. Y.		From G. R. Lumsden, Orig. No. 228.
6371	March, 1886	Presented	Foliated brown coal	1	Ratt, Germany		From G. R. Lumsden, Orig. No. 229.
6372	March, 1886	Presented	Fire opal	Indef.	Zamapan		From G. R. Lumsden, Orig. No. 231.
6373	March, 1886	Presented	Chrysolite	1	Dreis in d. Eifel		From G. R. Lumsden, Orig. No. 232.
6374	March, 1886	Presented	Serpentine	1	New Haven, Conn.		From G. R. Lumsden, Orig. No. 233.
6375	March, 1886	Presented	Diopside	3	Rothenkopf, Tyrol		From G. R. Lumsden, Orig. No. 235.
6376	March, 1886	Presented	Bastite	1	Baste in Hartz		From G. R. Lumsden, Orig. No. 236.
6377	March, 1886	Presented	Andularia feldspar	1	Mt. Stella, St. Goth'd		From G. R. Lumsden, Orig. No. 237.
6378	March, 1886	Presented	Actinolite	1	Connecticut		From G. R. Lumsden, Orig. No. 238.
6379	March, 1886	Presented	Agate with stilbite in cavity	1	Partridge Isl., N. S.		From G. R. Lumsden, Orig. No. 240.
6380	March, 1886	Presented	Lazulite	1	Krieglach, Styria		From G. R. Lumsden, Orig. No. 241.
6381	March, 1886	Presented	Turquois	Indef.	Khorassan, Persia		From G. R. Lumsden, Orig. No. 242.
6382	March, 1886	Presented	Fluorite	1	Freiberg, Germany		From G. R. Lumsden, Orig. No. 243.
6383	March, 1886	Presented	Vesuvianite	1	Monzoni, Tyrol		From G. R. Lumsden, Orig. No. 246.
6384	March, 1886	Presented	Pyrope	Indef.	Meronitz, Bohemia		From G. R. Lumsden, Orig. No. 249.
6385	March, 1886	Presented	Amber	2	Prussia		From G. R. Lumsden, Orig. No. 254.
6386	March, 1886	Presented	Pyrites and lead	1	Mont. County, N. Y.		From G. R. Lumsden, Orig. No. 257.
6387	March, 1886	Presented	Galena	1	Pennsylvania		From G. R. Lumsden, Orig. No. 263.
6388	March, 1886	Presented	Gold bearing quartz	1	Mariposa		From G. R. Lumsden, Orig. No. 269.
6389	March, 1886	Presented	Hornstone	1	Vermont		From G. R. Lumsden, Orig. No. 272.
6390	March, 1886	Presented	Beryl	1	New Haven, Conn.		From G. R. Lumsden, Orig. No. 277.
6391	March, 1886	Presented	Limestone crystals	1	Kentucky		From G. R. Lumsden, Orig. No. 279.
6392	March, 1886	Presented	Muscovite	1	Connecticut		From G. R. Lumsden, Orig. No. 281.
6393	March, 1886	Presented	Iron pyrites	1	Pennsylvania		From G. R. Lumsden, Orig. No. 288.
6394	March, 1886	Presented	Galena	1	Rossie, N. Y.		From G. R. Lumsden, Orig. No. 295.
6395	March, 1886	Presented	Stilbite	1	Sandy Cove, N. S.		From G. R. Lumsden, Orig. No. 297.
6396	March, 1886	Presented	Sand (for making glass)	Indef.	Mystic, Conn.		From G. R. Lumsden, Orig. No. 299.
6397	March, 1886	Presented	Asbestos	Indef.	Canada		From G. R. Lumsden, Orig. No. 300.

6398	March, 1886	Presented	Leelite	1	Chester Co, Pa.		From G. R. Lumsden, Orig. No. 301.
6399	March, 1886	Presented	Allanite	1			From G. R. Lumsden, Orig. No. 302.
6400	March, 1886	Presented	Asbestos	1	St. Albans, Canada		From G. R. Lumsden, Orig. No. 304.
6401	March, 1886	Presented	Crystals of beryl	1	New London, N. H.		From G. R. Lumsden, Orig. No. 305.
6402	March, 1886	Presented	Garnet sand	Indef.	Sturbridge, Mass		From G. R. Lumsden, Orig. No. 309.
6403	March, 1886	Presented	Crystal of mica	1	Haddam, Conn		From G. R. Lumsden, Orig. No. 310.
6404	March, 1886	Presented	Porcelain and china (from feldspar)	3	Delaware		From G. R. Lumsden, Orig. No. 311.
6405	March, 1886	Presented	Clay, pebbles and pyrites	Indef.	Lake Michigan		From G. R. Lumsden, Orig. No. 312.
6406	March, 1886	Presented	Kaolin	Indef.	Saxony, Germany		From G. R. Lumsden, Orig. No. 313.
6407	March, 1886	Presented	Moon-stone	Indef.	Haddam, Conn		From G. R. Lumsden, Orig. No. 318.
6408	March, 1886	Presented	Garnets	Indef.	Willimantic, Conn		From G. R. Lumsden, Orig. No. 338.
6409	March, 1886	Presented	Garnets	1	New Haven, Conn		From G. R. Lumsden, Orig. No. 340
6410	March, 1886	Presented	Piece of stalagmite	1	Howe's Cave, N. Y.		From G. R. Lumsden, Orig. No. 350.
6411	March, 1886	Presented	Foliated sulphate of lime	1	Connecticut		From G. R. Lumsden, Orig. No. 370.
6412	March, 1886	Presented	Asbestos	1	Norwalk, Conn		From G. R. Lumsden, Orig. No. 380.
6413	March, 1886	Presented	Rose quartz	1	New Britain, Conn		From G. R. Lumsden, Orig. No. 410.
6414	March, 1886	Presented	Chrysoberyl	7	Haddam, Conn		From G. R. Lumsden, Orig. No. 414.
6415	March, 1886	Presented	Feldspar	1	Fort Plain, N. Y.		From G. R. Lumsden, Orig. No. 415.
6416	March, 1886	Presented	Volcanic glass	Indef.	Crater of Owhyhee		From G. R. Lumsden, Orig. No. 490.
6417	March, 1886	Presented	Beryl (emerald)	Indef.	East Siberia		From G. R. Lumsden, Orig. No. 500.
6418	March, 1886	Presented	Glassy feldspar	1	Drachenfels, Germ		From G. R. Lumsden, Orig. No. 3.
6419	March, 1886	Presented	Gypsum	2			From G. R. Lumsden, Orig. No. 19.
6420	March, 1886	Presented	Iron pyrites	2			From G. R. Lumsden, Orig. No. 22.
6421	March, 1886	Presented	Chalcopyrite, galena and calcite	3			From G. R. Lumsden, Orig. No. 71.
6422	March, 1886	Presented	Siderite	1			From G. R. Lumsden, Orig. No. 91.
6423	March, 1886	Presented	Wood opal	1			From G. R. Lumsden, Orig. No. 109.
6424	March, 1886	Presented	Malachite (earthy)	Indef.			From G. R. Lumsden, Orig. No. 274.
6225	March, 1886	Presented	Tremolite	1			From G. R. Lumsden, Orig. No. 289.
6226	March, 1886	Presented	Black limestone	1			From G. R. Lumsden, Orig. No. 307.
6427	March, 1886	Presented	Agate (polished)	1			From G. R. Lumsden, Orig. No. 390.
6428	March, 1886	Presented	Beryl	5			From G. R. Lumsden, Orig. No. 460.
6429	March, 1886	Presented	Wood jasper	1			From G. R. Lumsden, Orig. No. 470.
6430	March, 1886	Presented	Petrified wood	1			From G. R. Lumsden.
6431	March, 1886	Presented	Concretions	4	Ill ?		From G. R. Lumsden.
6432	Jan., 1886	Presented	Ostrea bellaplicata	10	Sherman, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6433	Jan., 1886	Presented	Ostrea quadriplicata	10	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6434	Jan., 1886	Presented	Ostrea quadriplicata (or allied species)	5	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6435	Jan., 1886	Presented	Ostrea carinata	5	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6436	Jan., 1886	Presented	Gryphæa pitcheri	20	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6437	Jan., 1886	Presented	Gryphæa pitcheri variety	5	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6438	Jan., 1886	Presented	Gryphæa pitcheri variety	5	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6439	Jan., 1886	Presented	Exogyra ariatenum	15	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6440	Jan., 1886	Presented	Exogyra matheroniana	3	Ft. Worth, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6441	Jan., 1886	Presented	Cordium	1	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6442	Jan., 1886	Presented	Corbula graysonensis	2	Sherman, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6443	Jan., 1886	Presented	Lima wacoensis	1	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6444	Jan., 1886	Presented	Neitha texana	3	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6445	Jan., 1886	Presented	Terebratula wacoensis	15	Ft. Worth, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.

SPECIMENS REGISTERED IN THE GENERAL MUSEUM IN 1887–88.—(*Continued.*)

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of Specimen.	Locality.	Formation.	Collector and Remarks.
6446	Jan., 1886	Presented	Serpula communis	4	Denison, Tex	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6447	Jan., 1886	Presented	Serpula communis	1	Denison, Tex	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6448	Jan., 1886	Presented	Holaster elegans	2	Denison, Tex	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6451	Jan., 1886	Presented	Chonophyllum sedaliensis, White	4	Sedalia, Mo		From F. A. Sampson, Sedalia, Mo.
6452	Jan., 1886	Presented	Michelina expansa, White	4	Sedalia, Mo		From F. A. Sampson, Sedalia, Mo.
6453	Jan., 1886	Presented	Michelina placenta, White	2	Sedalia, Mo		From F. A. Sampson, Sedalia, Mo.
6454	Jan., 1886	Presented	Zaphrentis calceola, W & W	10	Sedalia, Mo		From F. A. Sampson, Sedalia, Mo.
6455	Jan., 1886	Presented	Flabellum wellesii, Conr	10	Jackson, Miss	Tertiary	From F. A. Sampson, Sedalia, Mo.
6456	Jan., 1886	Presented	Turbinola machurii	2	Jackson, Miss	Tertiary	From F. A. Sampson, Sedalia, Mo.
6457	Jan., 1886	Presented	Osteodes	5	Jackson, Miss	Tertiary	From F. A. Sampson, Sedalia, Mo.
6458	Jan., 1886	Presented	Cellopora	5	Jackson, Miss	Tertiary	From F. A. Sampson, Sedalia, Mo.
6459	Jan., 1886	Presented	Cellopora informata, Lonsd	8	Jackson, Miss	Tertiary	From F. A. Sampson, Sedalia, Mo.
8460	Jan., 1886	Presented	Heteropora tortilis	5	Jackson, Miss	Tertiary	From F. A. Sampson, Sedalia, Mo.
6461	March, 1886	Exchange	Diabase	1	Near Leesburg, Va		Smithsonian Inst., Washington, D. C.
6462	March, 1886	Exchange	Diabase	1	Addison, Maine		Smith. Inst., Wash., Orig. No. 37,019.
6463	March, 1886	Exchange	Diabase	1	York, Pa		Smith. Ins., Wash., Orig. No. 37,020
6464	March, 1886	Exchange	Diabase	1	Somerville, Mass		Smith. Inst., Wash., Orig. No. 37,633.
6465	March, 1886	Exchange	Olivine diabase	1	Lewiston, Maine		Smith. Inst., Wash., Orig. No. 37,618.
6466	March, 1886	Exchange	Norite	1	Nahant, Mass		Smith. Inst., Wash., Orig. No. 35,931.
6467	March, 1886	Exchange	Melaphyr	1	Brighton, Mass		Smith. Inst., Wash., Orig. No. 26,552.
6468	March, 1886	Exchange	Melaphyr	1	Brighton, Mass		Smith. Inst., Wash., Orig. No. 35,940.
6469	March, 1886	Exchange	Amphibolite	1	Chester, Mass		Smith. Inst., Wash., Orig. No. 37,655.
6470	March, 1886	Exchange	Hypersthene andesite	1	Mt. Shasta, Calif		Smith. Inst., Wash., Orig. No. 36,978.
6471	March, 1886	Exchange	Hornblende andesite	1	Mt. Shasta, Calif		Smith. Inst., Wash., Orig. No. 36,977.
6472	March, 1886	Exchange	Hornblende andesite	1	Mexico, Mexico		Smith. Inst., Wash., Orig. No. 37,711.
6473	March, 1886	Exchange	Elæolite syenite	1	N'r Deckertown, N.J.		Smith. Inst., Wash., D. C.
6474	March, 1886	Exchange	Elæolite syenite	1	S. Litchfield, Maine		Smith. Inst., Wash., Orig. No. 35,935.
6475	March, 1886	Exchange	Rhyolite	1	Zacatecas, Mexico		Smith. Inst., Wash., Orig. No. 37,994.
6476	March, 1886	Exchange	Rhyolite	1	Zacatecas, Mexico		Smith. Inst., Wash., D. C.
6477	March, 1886	Exchange	Rhyolite tuff	1	Zacatecas, Mexico		Smith. Inst., Wash., Orig. No. 37,737.
6478	March, 1886	Exchange	Rhyolite tuff	1	Douglass Co, Colorado		Smith. Inst., Wash., Orig. No. 36,778.
6479	March, 1886	Exchange	Rhyolite tuff	1	Zacatecas, Mexico		Smith. Inst., Wash., Orig. No. 37,693.
6480	March, 1886	Exchange	Basalt	1	Coast of Ireland		Smith. Inst., Wash., Orig. No. 37,610.
6481	March, 1886	Exchange	Basalt	1	Zacatecas, Mexico		Smith. Inst., Wash., Orig. No. 37,786.
6482	March, 1886	Exchange	Leucite basalt	1	Vesuvius, flow of 1872		Smith. Inst., Wash., Orig. No. 36,144.
6483	March, 1886	Exchange	Obsidian	1	Mono Craters, Calif		Smith. Inst., Wash., Orig. No. 29,631.
6484	March, 1886	Exchange	Satin spar	1	Pueblo, Mexico		Smith. Inst., Wash., Orig. No. 37,815.

6487	April, 1886	Geol. Survey	Cryptozoon Minnesotense, Winch	1	Mankato	Shakopee	N. H. Winchell.
6488	April, 1886	Geol. Survey	St. Lawrence limestone	7	St. Lawrence	St. Law.	N. H. Winchell.
6490	Sept., 1885	Geol. Survey	Orthis sandbergi, Winchell	1	Red Wing	St. Croix	N. H. Winchell from 6070.
6491	May, 1886	Geol. Survey	Kaolin	Indef.	Redwood Falls	Archæan	N. H. Winchell (from Col. J. B. Clough).
6492	May, 1886	Geol. Survey	Black loam soil ... Orig. No. 1	Indef.	Tracy, Minn	Drillings of the Tracy deep well.	N. H. Winchell, No. ft. 1, depth 1
6493	May, 1886	Geol. Survey	Yellowish pebbly clay " 2	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 19, depth 20
6494	May, 1886	Geol. Survey	Blue till " 3	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 100, depth 120
6495	May, 1886	Geol. Survey	Fine gravel, nearly black " 4	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 5, depth 125
6496	May, 1886	Geol. Survey	Fine blue clay " 5	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 20, depth 145
6497	May, 1886	Geol. Survey	Coarse gravel (similar to No. 4) " 6	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 20, depth 165
6498	May, 1886	Geol. Survey	Fine blue clay " 7	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 12, depth 177
6499	May, 1886	Geol. Survey	Fine sandstone, homogeneous " 8	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 20, depth 197
6500	May, 1886	Geol. Survey	Dark gray shale " 9	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 213, depth 410
6501	May, 1886	Geol. Survey	Fine light blue or greenish sand " 10	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 60, depth 470
6502	May, 1886	Geol. Survey	Blue clay " 11	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 43, depth 513
6503	May, 1886	Geol. Survey	Cretaceous grit " 12	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 32, depth 545
6504	May, 1886	Geol. Survey	Fine gray sandstone " 13	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 5, depth 550
6505	May, 1886	Geol. Survey	Blue clay like that of 6502 " 14	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 30, depth 580
6506	May, 1886	Geol. Survey	Angular, rounded grains of sand " 15	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 7, depth 587
6507	May, 1886	Geol. Survey	Dark unctuous, fine clay " 16	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 24, depth 611
6508	May, 1886	Geol. Survey	White, kaolinic clay " 17	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 8, depth 619
6509	May, 1886	Geol. Survey	White and gray quartz sand " 18	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 8, depth 627
6510	May, 1886	Geol. Survey	Same, but w some kaolinic m't'r'l " 19	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 10, depth 637
6511	May, 1886	Geol. Survey	White kaolin, with blue clay " 20	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 25, depth 662
6512	May, 1886	Geol. Survey	White angular quartz sand " 21	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 2, depth 664
6513	May, 1886	Geol. Survey	Same as last " 22	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 2, depth 666
6514	May, 1886	Geol. Survey	Same, but finer " 23	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 6, depth 672
6515	May, 1886	Geol. Survey	White sand w some kaolinic mt'l " 24	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 18, depth 690
6516	May, 1886	Geol. Survey	Reddish orthoclastic granite " 25	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 25, depth 715
6517	May, 1886	Geol. Survey	Drillings from Lakewood Cem't'ry well	Indef.	Minneapolis, Minn		N. H. Winchell, at 2118 ft.
6518	May, 1886	Presented	Trochus missouriensis (sw)	1	Kansas City, Mo	Coal meas.	From A. M. Light.
6520	Oct., 1886	A. F. Bechdolt	Fossil leaves	29	Nr source Rosebud riv, Mont		On Tongue river slope of the Wolf Mts.
6521	Oct., 1886	A. F. Bechdolt	Quercus Winchellii sp. nov		" "		Orig. No. 1, 1a. From 6520.
6522	Oct., 1886	A. F. Bechdolt	Hamamelites latifolius sp. nov		" "		Orig. No. 2, 3d, 4, 5, 11, 11a. 19, 20, 26. From 6520.
6523	Oct., 1886	A. F. Bechdolt	Cratœgus Wyomingiana, Lesq		" "		Orig. No. 2a, 2b, 7, 7a, 7b, 7c, 7e, 9, 11b, 14, 15, 18, 19a, 22a, 27, 30, and 31. From 6520.
6524	Oct., 1886	A. F. Bechdolt	Artocarpidium intermedium sp. nov		" "		Orig. No. 2c, 8. From 6520.
6525	Oct., 1886	A. F. Bechdolt	Ficus producta sp. nov		" "		Orig No. 3, 3a, 3b, 3c, 7d, 11c, 11f, 11g, 13a, 14a, 19b, 21a, 22, 28, 29. From 6520.
6526	Oct., 1886	A. F. Bechdolt	Hamamelites latifolius and seed of [V'b'm.		" "		Orig. No. 6, 6a. From 6520.
6527	Oct., 1886	A. F. Bechdolt	Quercus ettinghausii sp. nov		" "		Orig. No. 10. From 6520.
6528	Oct., 1886	A. F. Bechdolt	Cornus forshammeri Heer		" "		Orig. No. 12, 13. From 6520.
6529	Oct., 1886	A. F. Bechdolt	Ficus dura sp. nov		" "		Orig. No. 16, 25. From 6520.
6530	Oct., 1886	A. F. Bechdolt	Diospyros, calix of fruit		" "		Orig. No. 17. From 6520.
6531	Oct., 1886	A. F. Bechdolt	Viburnum heerii sp. nov		" "		Orig. No. 21. From 6520.
6532	Oct., 1886	A. F. Bechdolt	Cornus? specis undeterminable		" "		Orig. No. 23. From 6520.
6533	Oct., 1886	A. F. Bechdolt	Seed of Viburnum		" "		Orig. No. 24. From 6520.
6534	Oct., 1886	A. F. Bechdolt	Apeilopsis grandifolia sp. nov		" "		Orig. No. 32, 33. From 6520.
6535	Oct., 1886	A. F. Bechdolt	Seed of Viburnum? heerii? sp. nov		" "		Orig. No. 34. From 6520.
6537	Sept., 1885	H. B. Griffin	Concretion	1	Long Lake, Hennepin Co.	Cret.	Forty feet below surface. Presented.

SPECIMENS REGISTERED IN THE GENERAL MUSEUM IN 1887-88.—(*Continued.*)

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of Specimen.	Locality.	Formation.	Collector and Remarks.
6538	Sept., 1887	J. W. Bird	Wood	1	Martin Co., Minn	Drift	From a well 68 feet below surface.
6539	Sept., 1887	Hon. C. B. Little	Muscovite	1	Grafton, N. H		Presented.
6540	Sept., 1887	Rev. G. H. Trabert	Agate conglomerate	1	Duluth, Minn	Drift	Presented. From a boulder.
6541	Sept., 1887	York Iron Co	Charcoal	1	Black River Falls		Presented.
6542	Sept., 1887	Exchange	Nickeliferous jasper	1	Riddle, Dougl's Co., Or		From Wm. Q. Brown.
6543	Sept., 1887	Geol. Survey	Iron and copper	1	Tower, Minn		H. V. Winchell. Lee Mine.
6544	Sept., 1887	Geol. Survey	Hematite in quartz	1	Tower, Minn		H. V. Winchell. Lee Mine.
6545	Sept., 1887	Geol. Survey	Quartz crystals	4	Tower, Minn		H. V. Winchell.
6546	Sept., 1887	Geol. Survey	Hematite	1	Tower, Minn		H. V. Winchell.
6547	Sept., 1887	Geol. Survey	Red jasper conglomerate	1	Shores of Rainy Lake	Drift	H. V. Winchell.
6548	Sept., 1887	Geol. Survey	Coarse hornblende quartz	1	Winibigoshish dam		H. V. Winchell. From a boulder.
6549	Sept., 1887	Geol. Survey	Sand	Indef.	Rainy Lake		H. V. Winchell. Sec. 28, 71, 23.
6550	Sept., 1887	Geol. Survey	Iron from furnace	1	Black River Falls		N. H. Winchell.
6553	Nov., 1887	Geol. Survey	Hinckley sandstone	1	Cattle River quarry	Potsdam	N. H. Winchell.
6555	Jan., 1888	Presented	Coarse syenite	2	Red Wing	Drift	From Dr. G. A. Newman.
6556	Feb., 1888	Presented	Conocephalites hamulus, Hall	2	Winona, Minn	Silurian	From W. A. Finkelnburg.
6557	Feb., 1888	Presented	Platyceras minutissimum (Wal.)	3	Marine Mills, Minn	Silurian	From W. A. Finkelnburg.
6558	Feb., 1888	Presented	Bellerophon antiquatus (Wal.)	2	Osceola, Wis	Silurian	From W. A. Finkelnburg.
6559	Feb., 1888	Presented	Lingulepis pinnaformis, Owen	3	Taylors Falls, Minn	Silurian	From W. A. Finkelnburg. Short valve.
6560	Feb., 1888	Presented	Lingulepis pinnaformis	3	Taylors Falls, Minn	Silurian	From W. A. Finkelnburg. Long valve.
6561	Feb., 1888	Presented	Obolella polita, Hall	4	Dresbach, Minn	Silurian	From W. A. Finkelnburg.
6562	Feb., 1888	Presented	Chariocephalus whitfieldi, Hall	2	Wis. opp. Winona, M.	Silurian	From W. A. Finkelnburg. Glabella.
6563	Feb., 1888	Presented	Dikelocephalus osceola (Hall)	1	Osceola Mills, Wis	Silurian	From W. A. Finkelnburg. Head.
6564	Feb., 1888	Presented	Dikelocephalus osceola	1	Osceola Mills, Wis	Silurian	From W. A. Finkelnburg. Pygidium.
6565	Feb., 1888	Presented	Conocephalites minors Shum	3	Minneiska, Minn	Silurian	From W. A. Finkelnburg. Glabella.
6566	Feb., 1888	Presented	Conocephalites, Oweni Hall	4	Marine Mills, Minn	Silurian	From W. A. F'g. Glabella, fixed cheeks.
6567	Feb., 1888	Presented	Illænurus quadratus, Hall	2	Osceola Mills, Wis	Silurian	From W. A. Finkelnburg. Free cheeks.
6568	Feb., 1888	Presented	Illænurus quadratus	3	Osceola Mills, Wis	Silurian	From W. A. Finkelnburg. Glabella.
6569	Feb., 1888	Presented	Illænurus quadratus	2	Osceola Mills, Wis	Silurian	From W. A. Finkelnburg. Pygidium.
6570	Feb., 1888	Presented	Palæemæa minneiskænsis, Wal	8	Minneiska, Minn	Silurian	From W. A. Finkelnburg.
6576	Feb., 1888	Exchange	Felsyte	1	Sec. 17, T. 33, R. 5(E), Mo		From Erasmus Haworth, Orig. No. 316
6577	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 9, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 317
6578	Feb., 1888	Exchange	Quartz-porphory	1	Sec. 16, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 318
6579	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec. 16, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 319
6580	Feb., 1888	Exchange	Granite	1	Sec. 9, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 320
6581	Feb., 1888	Exchange	Quartz-porphyry	1	Missouri		From Erasmus Haworth, Orig. No. 321

6582	Feb., 1888	Exchange	Quartz-ironstone	1	Sec. 9, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 322
6583	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 9, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 323
6584	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 18, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 324
6585	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 9, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 325
6586	Feb., 1888	Exchange	Granite	1	Sec. 11, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 326
6587	Feb., 1888	Exchange	Granite	1	Sec. 9, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 327
6588	Feb., 1888	Exchange	Quartz-orthoclase	1	Sec. 20, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 328
6589	Feb., 1888	Exchange	Porphyry-orthoclase	1	Sec. 29, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 329
6590	Feb., 1888	Exchange	Porphyry-orthoclase	1	Sec. 21, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 330
6591	Feb., 1888	Exchange	Porphyry-orthoclase	1	Sec. 28, T. 33, R. 5, Mo		From Erasmus Haworth, Orig. No. 331
6592	Feb., 1888	Exchange	Orthoclase-porphyry	1	Sec. 29, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 822
6593	Feb., 1888	Exchange		1	Sec. 32, T. 33, R. 5, Mo.		From Erasmus Haworth, O ig. No. 333
6594	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec. 32, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 334
6595	Feb., 1888	Exchange	Altered dioryte (?)	1	Sec. 32, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 335
6596	Feb., 1888	Exchange	Chert	1	Sec. 32, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 336
6597	Feb., 1888	Exchange		1	Sec. 32, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 337
6598	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 31, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 338
6599	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 31, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 339
6600	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 6, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 340
6601	Feb., 1888	Exchange	Orthoclase-porphyry	1	Sec. 6, T. 32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 341
6602	Feb., 1888	Exchange	Diabase	1	Sec. 16, T. 32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 342
6603	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec. 16, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 343
6604	Feb., 1888	Exchange	Orthoclase-porphyry	1	Sec. 15, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 314
6605	Feb., 1888	Exchange	Granite	1	Sec. 15, T. 33, R. 5, Mo		From Erasmus Haworth, Orig. No. 345
6606	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 27, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 347
6607	Feb., 1888	Exchange	Diabase	1	Sec. 17, T. 33, R. 6, Mo.		From Erasmus Haworth, Orig. No. 348
6608	Feb., 1888	Exchange	Diabase	1	Sec. 17, T. 33, R. 6, Mo.		From Erasmus Haworth, Orig. No. 349
6609	Feb., 1888	Exchange		1	Sec. 19, T. 33, R. 6, Mo.		From Erasmus Haworth, Orig. No. 350
6610	Feb., 1888	Exchange		1	Sec. 19, T. 33, R. 6, Mo.		From Erasmus Haworth, Orig. No. 351
6611	Feb., 1888	Exchange		1	Sec. 5, T. 32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 352
6612	Feb., 1888	Exchange		1	Mo.		From Erasmus Haworth, Orig. No. 353
6613	Feb., 1888	Exchange		1	Mo.		From Erasmus Haworth, Orig. No. 354
6614	Feb., 1888	Exchange		1	Mo.		From Erasmus Haworth, Orig. No. 355
6615	Feb., 1888	Exchange		1	Mo.		From Erasmus Haworth, Orig. No. 356
6616	Feb., 1888	Exchange		1	Mo.		From Erasmus Haworth, Orig. No. 357
6617	Feb., 1888	Exchange	Duplicate samples	14	Mo.		From Erasmus Haworth, Orig. No. .....
6618	Feb., 1888	Exchange	Altered diabase (?)	1	Sec. 4, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 358
6619	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 19, T, 33, R. 6, Mo.		From Erasmus Haworth, Orig. No. 360
6620	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 14, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 361
6621	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 18, T, 33, R. 6, Mo.		From Erasmus Haworth, Orig. No. 362
6622	Feb., 1888	Exchange	Granite	1	Sec. 4, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 363
6623	Feb., 1888	Exchange	Granite	1	Sec. 3, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 364
6624	Feb., 1888	Exchange	Diabase	1	Sec. 8, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 365
6625	Feb., 1888	Exchange	Diabase-porphyry	1	Sec. 10, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 366
6626	Feb., 1888	Exchange	Granite	1	Sec. 10, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 367
6627	Feb., 1888	Exchange	Granite	1	Sec. 11, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 368
6628	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 11, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 369
6629	Feb., 1888	Exchange	Diabase	1	Sec. 14, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 370

SPECIMENS REGISTERED IN THE GENERAL MUSEUM IN 1887–88.—(*Continued.*)

Serial No.	Obtained.		Name.	Number of Specimens.	Locality.	Formation.	Collector and Remarks.
	When.	Whence.					
6630	Feb., 1888	Exchange	Granite	1	Sec.14, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 371
6631	Feb., 1888	Exchange	Quartz-porphyry	1	Sec.14, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 372
6632	Feb., 1888	Exchange	Decomposed conglomerate	1	Sec.13, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 373
6633	Feb., 1888	Exchange	Quartz-porphyry	1	Sec.13, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 374
6634	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec.13, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 375
6635	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec.24, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 376
6636	Feb., 1888	Exchange	Diabase	1	Sec.25, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 377
6637	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec.25, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 378
6638	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec.26, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 379
6639	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec.35, T.33, R. 5, Mo.		From Errsmus Haworth, Orig. No. 380
6640	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec. 3, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 381
6641	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 3, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 382
6642	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec.10, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 383
6643	Feb., 1888	Exchange		1	Sec.16, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 384
6644	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.21, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 385
6645	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.21, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 386
6646	Feb., 1888	Exchange	Plagioclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 387
6647	Feb., 1888	Exchange	Altered diabase	1	Mo.		From Erasmus Haworth, Orig. No. 388
6648	Feb., 1888	Exchange	Plagioclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 389
6649	Feb., 1888	Exchange	Plagioclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 390
6650	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.17, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 391
6651	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.20, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 392
6652	Feb., 1888	Exchange	Marble	1	Sec.18, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 393
6653	Feb., 1888	Exchange	Limestone	1	Sec.19, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 394
6654	Feb., 1888	Exchange	Quartzyte	1	Sec.19, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 395
6655	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 7, T.32, R. 5, Mo.		From Erasmus Haworth. Orig. No. 396
6656	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec. 7, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 397
6657	Feb., 1888	Exchange	Orthoclase-porphyry	1	Sec. 8, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 398
6658	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.30, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 399
6659	Feb., 1888	Exchange	Orthoclase-porphyry	1	Sec.30, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 400
6660	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.19, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 401
6661	Feb., 1888	Exchange	Orthoclase-porphyry	1	Sec.15, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 402
6662	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.14, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 403
6663	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.23, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 404
6664	Feb., 1888	Exchange	Altered diabase	1	Sec.28, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 405
6665	Feb., 1888	Exchange	Plagioclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 406

6666	Feb., 1888	Exchange	Plagioclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 407
6667	Feb., 1888	Exchange	Epidote-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 408
6668	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 409
6669	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 410
6670	Feb., 1888	Exchange	Diabase	1	Mo.		From Erasmus Haworth, Orig. No. 411
6671	Feb., 1888	Exchange	Orthoclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 412
6672	Feb., 1888	Exchange	Orthoclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 413
6673	Feb., 1888	Exchange	Diabase	1	Mo.		From Erasmus Haworth, Orig. No. 414
6674	Feb., 1888	Exchange	Diabase	1	Mo.		From Erasmus Haworth, Orig. No. 415
6675	Feb., 1888	Exchange	Diabase	1	Mo.		From Erasmus Haworth, Orig. No. 416
6676	Feb., 1888	Exchange	Rewdanskite (?)	1	Riddles, Oregon		From W. Q. Brown.
6677	Feb., 1888	Exchange	Garnierite and serpentine	1	Riddles, Oregon		From W. Q. Brown.
6678	Feb., 1888	Exchange	Chrysoprase	1	Riddles, Oregon		From W. Q. Brown.
6679	Feb., 1888	Exchange	Garnierite (soft)	1	Riddles, Oregon		From W. Q. Brown.
6680	Feb., 1888	Exchange	Garnierite and chromic iron	1	Riddles, Oregon		From W. Q. Brown.
6681	Feb., 1888	Presented	Copper ore	1	Globe City, Arizona		From J. L. Vivian.
6682	Feb., 1888	Presented		1			
6683	April, 1888	Presented	Geyserite	Indef.	Lindsborg, Kans		From J. H. Udden.
6684	April, 1888	Exchange	Pentamerus oblongus, Saw	2	Springfield, Ohio	Niagara	From W. S. Hoskinson.
6685	April, 1888	Exchange	Zaphrentis	2	Delaware Co., Ohio	Dev. Corn.	From W. S. Hoskinson.
6686	April, 1888	Exchange	Zaphrentis	2	Delaware Co., Ohio	Dev. Corn.	From W. S. Hoskinson.
6687	April, 1888	Exchange	Orthocerata	2	New Carlisle, Ohio	Clinton	From W. S. Hoskinson.
6688	April, 1888	Exchange	Orthocerata	1	New Carlisle, Ohio	Clinton	From W. S. Hoskinson.
6689	April, 1888	Exchange	Orthocerata	1	Miamisburg, Ohio	U.H'dn riv	From W. S. Hoskinson.
6690	April, 1888	Exchange	Cyathophylloid	8	Springfield, Ohio	Niagara	From W. S. Hoskinson.
6691	April, 1888	Exchange	Cyathophylloid	4	New Carlisle, Ohio	Clinton	From W. S. Hoskinson.
6692	April, 1888	Exchange	Strophodonta-hemispherica	1	Delaware Co., Ohio	Dev. Corn.	From W. S. Hoskinson.
6693	April, 1888	Exchange	Strophomena-rhomboidalis	2	Waldron, Ind	Niagara	From W. S. Hoskinson.
6694	April, 1888	Exchange	Strophomena-rhomboidalis	2	New Carlisle, Ohio	Clinton	From W. S. Hoskinson.
6695	April, 1888	Exchange	Illænus daytonensis	4	New Carlisle, Ohio	Clinton	From W. S. Hoskinson.
6696	April, 1888	Exchange	Streptelamina	4	Miamisburg, Ohio	L. Sil	From W. S Hoskinson.
6697	April, 1888	Exchange	Favosites	2	Delaware Co., Ohio	Dev. Corn.	From W. S. Hoskinson.
6698	April, 1888	Exchange	Favistella	2	New Carlisle, Ohio	Clinton	From W. S. Hoskinson.
6699	April, 1888	Exchange		2		Dev. Corn.	From W. S. Hoskinson.
6700	April, 1888	Exchange		1	Miamisburg, Ohio	Cincin	From W. S. Hoskinson.
6701	April, 1888	Exchange	Lithostration	1	Springfield, Ohio	Niagara	From W. S. Hoskinson.
6702	April, 1888	Exchange	Eucalyptocrinus crassus	3	Springfield, Ohio	Niagara	From W. S. Hoskikson.
6703	April, 1888	Exchange	Eucalyptocrinus crassus	2	Waldron, Ind		From W. S Hoskinson.
6704	April, 1888	Exchange	Eucalyptocrinus (roots)	2	Waldron, Ind		From W. S. Hoskinson.
6705	April, 1888	Exchange	Crinoid stems	8	New Carlisle, Ohio	Clinton	From W. S. Hoskinson.
6706	April, 1888	Exchange	Crinoid	1	Springfield, Ohio	Niagara	From W. S. Hoskinson.
6707	April, 1888	Exchange	Monticulipora dalii	2	Miamisburg, Ohio		From W. S. Hoskinson.
6708	April, 1888	Exchange	Calymene niagarensis	1	Springfield, Ohio		From W. S. Hoskinson.
6709	April, 1888	Exchange	Calymene senaria	1	Oxford, Ohio	U. Hud. riv	From W. S. Hoskinson.
6710	April, 1888	Exchange	Lichas brevipes	1	New Carlisle, Ohio	Clinton	From W. S. Hoskinson.
6711	April, 1888	Exchange	Spirifera mucronata	1	Miamisburg, Ohio		From W. S. Hoskinson.
6712	April, 1888	Exchange	Atrypa reticularis	4	Delaware Co., Ohio	Dev. Corn.	From W. S. Hoskinson.
6713	April, 1888	Exchange	Platystoma niagarense	2	New Carlisle, Ohio	Clinton	From W. S. Hoskinson.

SPECIMENS REGISTERED IN THE GENERAL MUSEUM IN 1887-88.—(*Concluded.*)

Serial No.	Obtained.		Name.	Number of Specimens.	Locality.	Formation.	Collector and Remarks.
	When.	Whence.					
6714	April, 1888	Exchange	Platystoma niagarense	6	Waldron, Ind		From W. S. Hoskinson
6715	April, 1888	Exchange	Eichwaldia reticulata	2	Waldron, Ind	Niagara	From W. S. Hoskinson.
6716	April, 1888	Exchange	Zygospira modesta	3	Miamisburg, O		From W. S. Hoskinson.
6717	April, 1888	Exchange	Leptæna sericea	3	Miamisburg, O	Up. Hud. R	From W. S. Hoskinson.
6718	April, 1888	Exchange	Protarea vetusta, Hall	2	Miamisburg, O		From W. S. Hoskinson.
6719	April, 1888	Exchange	Murchisonia bellicincta	2	Miamisburg, O		From W. S. Hoskinson.
6720	April, 1888	Exchange	Cyclonema bilix	1	Miamisburg, O		From W. S. Hoskinson.
6721	April, 1888	Exchange	Pleurotomaria tropidophora	2	Miamisburg, O		From W. S. Hoskinson.
6722	April, 1888	Exchange	Orthis sinuata	2	Miamisburg, O	Up. Hud. R	From W. S. Hoskinson.
6723	April, 1888	Exchange	Orthis subquadrata	9	Miamisburg, O		From W. S. Hoskinson.
6724	April, 1888	Exchange	Orthis acutilirata	4	Miamisburg, O		From W. S. Hoskinson.
6725	April, 1888	Exchange	Orthis lynx	5	Miamisburg, O		From W. S. Hoskinson.
6726	April, 1888	Exchange	Orthis faustra	1	New Carlisle, O	Clinton	From W. S. Hoskinson.
6727	April, 1888	Exchange	Streptorhynchus sulcatus	1	Miamisburg, O	Up. Hud. R	From W. S. Hoskinson.
6728	April, 1888	Exchange	Streptorhynchus planumbonus	3	Miamisburg, O		From W. S. Hoskinson.
6729	April, 1883	Exchange	Streptorhynchus nutans	3	Miamisburg, O		From W. S. Hoskinson.
6730	April, 1888	Exchange	Strophomena alternata	2	Miamisburg, O		From W. S. Hoskinson.
6731	May, 1838	Presented	Pseudomorph of magnetite and pyrite after garnet	1	Negaunee, Mich		From N. H. Winchell.
6732	May, 1888	Presented	Rock 60 feet from surface	4	Little Falls, Minn		From N H. Winchell, at L. F's Brew'y.
6733	May, 1888	Presented	Pyrite from blue till	1	Minnesota	Drift	From N. H. Winchell.
6734	May, 1888	Presented	Pseudomorph hematite	1	Marquette i. r., Mich.		From N. H. Winchell.
6735	May, 1888	Exchange	Tin ore	1	Pennington Co., Dak.		From Sam. Scott, Morgan's Tin Mine.
6736	May, 1888	Exchange	Greisen rock	1	Pennington Co., Dak.		From Sam. Scott, Everly Tin Mine.
6737	May, 1888	Exchange	Spodumene	1	Pennington Co., Dak.		From Sam. Scott, Etta Tin Mine.
6738	May, 1888	Exchange	Rose quartz	1	Pennington Co., Dak.		From Sam. Scott, Red Rose Mine.
6739	May, 1888	Exchange	Albite	1	Pennington Co., Dak.		From Sam. Scott, Etta Tin Mine.
6740	May, 1888	Presented	Albite	2	Amelia Co., Va		G. L. English & Co., Amelia C't House.
6741	May, 1888	Presented	Lingula acuminata	1	New York	Medina Sand.	From Rev. H. Herzer.
6770	Aug., 1888	Presented	Piece of cedar wood	1	Near Camden, Minn.	Drift	From Cyrus R. Stone.
6824	Oct., 1888	Presented	Minerals from Mt Vesuvius	12	Italy		From Mrs. M. J. Wilkin.
6825	Oct., 1888	Presented	Incrustation on gneiss	1	Near Swarthm're col, Pa.		From Miss M. L. Sanford.
6826	Oct., 1888	Presented	Meerschaum	1	Norway		Prof. J. Breda (From the edge of a glacier below Sulitind, Norway.)
6527	Oct., 1888	Presented	Lignite	1	St. Paul, Minn	Drift	Prof. N. H. Winchell.

VI.

APPENDIX.—LIST OF RECENT GEOLOGICAL PUBLICATIONS RELATING TO THE CRYSTALLINE ROCKS.

VI.

List of American Publications Between 1872 and 1889 That Have Some Relation to the Crystalline Rocks of the Northwest.

This list of publications, while embracing most of those issued since 1872 bearing on the crystalline rocks of Minnesota, or of the Northwest, is not presumed to be complete, and it is desired that geologists who discover omissions will communicate with the writer in order that, in a future report, such additions may be made as will make the list perfect.

The list of papers and other publications prepared by Whitney & Wadsworth and published in the *Bulletin of the Museum of Comparative Zoology*, Cambridge (Geol. Series, Vol. I.), carried the record up to 1880. By the aid of that, and with the assistance of Mr. Geo. H. Barton, of the Institute of Technology, Boston, who examined some serial publications that could not be consulted at Minneapolis, the catalogue may be considered to embrace most of the publications of American geologists on the crystalline rocks of the central and eastern portions of the United States and of Canada, between 1872 and 1889. There are, however, some important serials that have not been consulted.

1873.

BELL, ROBT.

Report on the country between lake Superior and lake Winnipeg. Geol. Sur. of Can., Report of Progress. Montreal, 1872–73, pp. 87–111.

BROOKS, T. B.

Geological Survey of Michigan, with maps, 1869–73, i.; Part I., Iron-bearing Rocks, 319 pp.; Part II., Copper-bearing Rocks, R. Pumpelly and A. R. Marvine, 143 pp.; Part III., Palæozoic Rocks, Charles Rominger, 105 pp.; ii., 298 pp., contains papers by Messrs. Brooks, Julien, Wright, Jenney, and Tuttle.

DANA, J. D.

On the Quartzite, Limestone, and Associated Rocks of the vicinity of Great Barrington, Mass., Am. J. Sci., 3d Series, Vol. 5, pp. 47–53, 87–91; Vol. 6, pp. 257–278.

FOSTER, J. W.

Ancient Mining by the Mound-builders in the "Prehistoric Races of the United States." Chicago, 1873, pp. 361–374.

HITCHCOCK, C. H.

Classification of the Rocks of New Hampshire. Proc. Boston Soc. Nat. Hist., Vol. 15, pp. 304–307.

HUNT, T. STERRY.

The Geology of the North Shore of Lake Superior. (Supplementary Note.) Trans. Am. Inst. Min. Eng., 1873, ii., 58, 59.

IRVING, ROLAND D.

On some points in the Geology of Northern Wisconsin. Trans. Wisc. Acad. Sci., 1873–74, ii., 107–119.

MARVINE, A. R.

Geology of Michigan. Part II., 1873.

NICHOLSON, H. ALLEYNE.

On the Geology of the Thunder bay and Shabendowan Mining Districts on the North Shore of lake Superior. Quart. Jour. Geol. Soc., 1873, xxix., 17–24.

PUMPELLY, RAPHAEL.

The Paragenesis and Derivation of Copper and its Associates on lake Superior. Am. Jour. Sci., 1872 (3), iii., 188–198, 243–258, 347–353; Leonhard's Jahrbuch, 1872, pp. 538–540; Geol. of Michigan, Part II., 1873.

SELWYN, ALFRED R. C.

Notes of a Geological Reconnoissance from lake Superior to Fort Garry. Geol. Surv. of Canada, Report of Progress. Montreal, 1872–73, pp. 8–18.

WHITTLESEY, CHARLES.

On the cause of the Transient Fluctuations of Level in lake Superior. Proc. Am. Assoc. Adv. Sci., 1873, xxii., Part II., 42–46.

WINCHELL, ALEXANDER.

The Diagonal System in the Physical Features of Michigan. Am. Jour. Sci., 1873 (3), vi., 36–40.

WINCHELL, N. H.

Geological and Natural History Survey of Minnesota. First annual report, 113 pp.

WING, A. T.

Concerning the Spontaneous Movements and Fractures of Rock, at Quarry of W. N. Flynt, Monson, Mass. Proc. Bost. Soc. Nat. Hist., Vol. 16, pp. 41–42.

1874.

ALLEN, J. A.

Metamorphism Produced by the Burning of Lignite Beds in Dakota and Montana Territories. Proc. Boston Soc. Nat. Hist., Vol. 16, pp. 246–262.

BROWN, A. J.
The Formation of Fissures and the Origin of Their Mineral Contents. Trans. Am. Inst. Min. Eng., 1874, ii., 215–219.

DANA, JAMES D.
Manual of Geology, New York, 1st ed., 1862, 800 pp.; 2d ed., 1874, 828 pp.; 3d ed., 1880, 911 pp.

DOUGLAS, JAMES.
The Native Copper Mines of lake Superior. Quart. Jour. Sci., 1874, xi., 162–180; Canadian Nat. and Geol., 1874 (2), vii., 318–336.

IRVING, ROLAND D.
On the Age of the Copper-bearing Rocks of lake Superior; and on the Westward Continuation of the lake Superior Synclinal. Am. Jour. Sci., 1874 (3), viii., 46–56.

LE CONTE, J. L.
On Coracite, a new ore of Uranium. Am. Jour. Sci., 1874 (2), iii., 173–175.

M'KELLAR, PETER.
Mining on the North Shore of lake Superior. Toronto, 1874, 26 pp.

NEWBERRY, J. S.
The Iron Resources of the United States. International Review, 1874, ii., 754–780.

NICHOLSON, H. ALLEYNE.
On the Mining District on the North Shore of lake Superior. Trans. of North of England Inst. of Min. and Mech. Eng. Newcastle-on-Tyne, 1874–75, xxiv., 237–249, with maps.

WHITTLESEY, CHARLES.
Sudden Fluctuations of Level in Quiet Waters. Records of Observations. Proc. Am. Assoc. Adv. Sci., 1874, xxiii., 139–143.

1875.

AKERMANN, H. W.
Die Kupferführenden Schichten am lake Superior. Sitzungs-Berichte der naturwissenschaftlichen Gesellschaft Isis in Dresden, 1875, pp. 101–105.

BELL, ROBERT.
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Israel C. Russell

THE GEOLOGICAL

AND

NATURAL HISTORY SURVEY

OF MINNESOTA.

The Eighteenth Annual Report, for the year 1889.

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ADDRESS.

THE UNIVERSITY OF MINNESOTA,
MINNEAPOLIS, March 3, 1890.

To the President of the University.

DEAR SIR: With the round of another year I herewith report the progress made in the geological and natural history survey of the state. During the year there has been considerable interruption incident to the removal and installment of the museum and survey headquarters in the new Science Hall. This was aggravated by the fire which unfortunately broke out in the building in the latter part of December, and which, while not consuming much, yet so damaged the rooms and their contents that it necessitated the renovation of the entire building, and the cleaning of most of the specimens and apparatus. This report gives an idea of the progress that is being made in the intricate geology of the north-eastern part of the state, and of the economic resources that are being developed there. That part which discusses the iron ores of the state is planned to be published as a separate bulletin of the survey.—Bulletin No. 6. It is accompanied by numerous illustrations and a geological map.

Respectfully, your obedient servant,
N. H. WINCHELL,
State Geologist and Curator of the General Museum.

REPORT.

I.

Summary Statement for 1889.

There was not much field-work done in 1889. This was due to the change from field-work to office and laboratory work which was announced in the last annual report incident on the commencement of the final report on the northern part of the state. In July, however, a special reconnoissance was made of the iron-deposits and the mines at Tower and Ely, in order to get some details of the relations of the ore-bodies to the country rock as developed about the works, and of the methods of mining and transportation. In some directions this review was extended into the surrounding country whenever there was promise of new facts either economic or scientific. This re-examination resulted in the acquirement of of many interesting facts of detail, and in the establishment or the rejection of some hypotheses as to the origin of the ore bodies, and the genetic history of the rocks embracing them. It was thought that with the light of the field observations made during the previous three years fresh in mind, and with all the known theories of the ore and of the general geology that had been proposed whether by the Minnesota survey or by others, immediately and continually under test and application, such a careful investigation would be a valuable preparation for the discussion of the crystalline rocks which was contemplated, and especially for the exposition of the iron ores contained in Bulletin No. 6. This review was made in conjunction with Mr. H. V. Winchell; and inasmuch as the progress of the investigation here, as elsewhere, has been frequently the result of our joint work and mutual co-operative study, the bulletin devoted to the iron ores herewith transmitted bears our joint authorship.

Within the past year two other bulletins have been published, viz., *Natural Gas in Minnesota,* and *The History of Geological Surveys in Minnesota.*

The Legislature of 1889 failed to make provision for the publication of the two final volumes of the survey report referred to in the

last annual statement. This failure, however, was not due so much to indifference on the part of the Legislature as a whole, as to the unfriendly manipulation of some of the committees, and the neglect of the public officials having in charge the estimates and recommendations for the current expenses. The reports of the survey were eagerly sought by all the legislators, both for themselves and for their friends. They were aggrieved when they found that by law this distribution was not wholly gratuitous and instant, and they desired the publication of the final volumes as fast as they can be got ready. The bill for a law, however, making provision by a money appropriation for the printing of the manuscripts now on hand was delayed by the chairman of the committee having it in charge until it was too late to get the appropriation allowed by the general finance committee and acted on by both houses of the Legislature. The same will be offered for publication at the next session of the Legislature (1891).

In the summer of 1889 the museum and all the paraphernalia of the survey were removed from the "main building" of the University, where it has been located since 1872, to the new Science Hall. The building was not yet completed, but the removal had to be made to give opportunity to fit the old rooms for other use prior to the opening of the fall term of the University. The building was nearly finished, and some work had been given to the museum and to the equipment of the various rooms, and plans had been entered upon for office and laboratory work, when another interruption was suffered (Dec. —) by the (supposed) spontaneous starting of a fire in the engine room, where painters had been at work with naphtha and white lead. This kept the survey work largely in abeyance till about Feb. 15, 1890, when the building had been again sufficiently restored, and the damaged rooms renovated, to permit of their regular occupancy. Thus it will be seen that the work of more than six months has been so broken and unsatisfactory that it will not permit a very cheerful view to be taken of the aggregate progress of the year. Still, unless some other unfavorable cause interfere, the commodious rooms now occupied by the survey for office, drafting room, laboratories, museum and storage, will, when fully equipped with apparatus, and the library with reference books, warrant the expectation that the nicer researches that remain to be done in order to "finish" the survey of the state, will go forward with ease and dispatch.

The Museum now needs replenishing. The room that is given to it is more than four times as large as that which it occupied in the other building, and numerous new cases ought to be constructed.

This is true particularly of the zoological collections, which have been put in the special charge of professor Nachtrieb. In the geological museum, while the old cases have been refitted and made to answer for the present, there is a need of mineralogical specimens and there will be soon need of other cases for exhibition. Some of the specimens of the Kunz collection purchased in 1376 have been lost. Many of them are permanently removed from exhibition in the museum and stored in the geological lecture room. Indeed many of the unique and attractive specimens formerly kept in the museum for exhibition have been missing from their places from that cause for some years, and some have been badly damaged. The mineral collection has thus inevitably deteriorated, and ought to be replenished by occasional purchase. Of course donations aid in keeping the collections (i. e. the cases) apparently full, but donations do not supply first-class material.

State Park. I wish to call the attention of the regents, and through their report, the attention of the public and the Legislature to the propriety of asking a reservation of land for a state park in some section in the northern part of the state. The geographic positon of Minnesota is on that border land which exhibits the transition of the forested area into the prairie. It hence preserves the faunal and floral characteristic of both, and within its territory must be studied by naturalists the mutual modifications and interchanges which the near neighborhood and contact of different physical features always imprint on the native vegetation and animal life found therein. By settlement and long habitation the natural conditions are destroyed and the natural laws that could perhaps be discovered by an examination of them in their original state, are never known. Hence as long as the natural conditions exist the state of Minnesota will be visited by students and collectors interested in natural science for the purpose of investigation, and this will bring Minnesota into prominent recognition in scientific literature and secondarily into scientific and economic research. It hence behooves the State to preserve, to such extent as may be found desirable and feasible, these natural and aboriginal conditions, and for this purpose there is no better method than to reserve from sale and settlement some considerable tract where they may not be destroyed.

Again the state should have a large public park because of the healthful resort that it ould afford for those living in cities, and for those who, coming from further south, seek in summer the invigorating effect of northern latitudes. The attractions of a multitude of lakes, rivers and rivulets of limpid and pure water, are

confined in the United States, to the northern tier, where the tumuli of the glacial epoch formed the depressions and natural reservoirs of gravel and sand, such as mark its moraines from Maine to Minnesota. In Dakota these lines of tumuli pass across the prairies northwestward to the line of British America and do not return again sensibly within the United states. Hence it is within Minnesota that exists the last opportunity to preserve the pristine conditions of that unique combination of physical and faunal relations which alike distinguishes them from all other natural surface conditions in the United States, and has attracted to them always the venturesome, wandering explorer, the artist, the geologist, and the hardy frontier settler.

This park should be located either in the region northeast of lake Superior, enclosing some of the rock-bordered and rock-bottomed lakes that are a natural curiosity to every traveler, or in the area about the head waters of the Mississippi. General J. H. Baker, when surveyor-general of Minnesota, some years ago, urged that such a park be established on the international boundary line north of lake Superior, and specified the region of lake Saganaga. Since then, the region of the Itascan source of the Mississippi river has come into prominence, and it has served as the topic of several explorations and new "journals," which have given it already a renown equal to the earlier historic interests that cling to it since the days of Lieut. Allen, of H. R. Schoolcraft and Jean Nicollet. These artificial elements enter strongly into the question of making the selection for a state park, and bear heavily in favor of the sources of the Mississippi for such a selection. There is, fortunately, a perfect exemplification of the natural surface features that characterize the glacial moraines of the state within a few miles of the Itasca lake, and, indeed, they give outline and location to the entire Itascan basin, and would thus serve to embrace, within easy access or in combination, both the natural and the artificial considerations. This region is, moreover, remote from lake Superior, and its attractions, by contrast with the surrounding country, would be hightened in the mind of every visitor. Whereas, in the northeastern part of the state, lake Superior and its attendant waters and surrounding hills, dominate the district, so that no selection could be made whose attractions would rise above those of the great lake itself.

It is presumed that there would be no difficulty, whether in the northeastern or the northwestern part of the state, or even in both, in getting the consent and cooperation of the United States government by the withdrawal of the lands concerned from the market,

and perhaps of any private parties who may have received some of the lands from the United States, or from the State of Minnesota. At any rate, no time should be lost in entering upon the project, because of changes and increased difficulties that will render it impossible not many years hence.

The laboratory and office of the survey ought to be supplied with apparatus and books needed for the work that lies immediately before it. This is a matter of absolute necessity. It were better that all other expenses cease entirely till there be sufficient funds for this necessity, or that a special appropriation be made by the Legislature to provide them.

II.

Record of Field-Observations in 1888.

On the Mesabi Iron Range. Mallmann's mining camp is on the Duluth and Iron Range railroad, about two miles south of Hinsdale on the Giant's range of granite hills. The working is for iron ore. There are a number of pits or shafts sunk to the rock, from 15 to 50 feet in depth, and they have uniformly encountered the same magneto-bedded rock that Chester did on the Mesabi range a few miles further northeast* and of a character identical with that seen near the west end of Gunflint lake,** both being a part of the Animike, and probably in the lower portion of it. About half a mile further south is a cut by the railroad in real Animike slate. Some of the ore he finds is hematite, and he hopes to get enough that is hematite to warrant his enterprise. This working is just west from the "red cut" which is mentioned in the 13th report in giving a description of a trip to Tower, and in one of the shafts he has struck this red hematite mass. The rock seems to be more rotted in this red mass.

This magneto-bedded rock is nondescript. It has been referred to sometimes as quartzyte, but it generally contains not enough free quartz to entitle it to that designation. It is gray, medium-grained, sometimes fine-grained, has a mineral, apparently a feldspar, that changes by rot to a white kaolinic substance, or to a rusty powder, and is the rock in which is scattered the magnetite ore both here and at Gunflint lake, as well as at Chub (Akeley) lake. This ore is in lenticular bunches, elongated in the direction of the general bedding, and is generally not pure magnetite, but is seen to increase and fade again in the midst of the rock, sometimes

* See Eleventh Annual Report, p. 156

** See Sixteenth Report, pp. 80, 267.

extending in parallel bands from half an inch to an inch wide, and a foot or more in length. It is this same rock which accompanies the hematite, which inspires Mallmann with fresh hope. Apparently the hematite is disseminated in it in the same way as the magnetite. Mallmann is confident the ore here is the same as the ore mined at Tower, and in the same kind of rock—a mistake which we tried to correct. There is no question but the vertical greenish schists and graywackes seen at the Tower mines are repeated south of the Giant's range, and pass uncomformably below the Animike along the line of strike all the way from Gunflint lake to this point, and that they may be encountered after passing through the slates and quartzytes of the Animike. It is likely also that they are as apt to carry iron-ore lenses on the south side of that range as on the north side. But owing to the prevalence of the drift, and the concealment of these schists by the overlapping of the Animike, it would be a herculean and problematical task to seek to find such ore bodies by shafting through the Animike. It would not be impossible that a shaft should go down through the Animike, and should encounter one of these ore bodies in the Keewatin, but the chances against such an event would be many thousands to one. It is probable therefore that all the ore found by Mallmann here is from the Animike beds.

Observations about Tower. We visited again the vertical black slaty crag north of Tower, in the southern slope of the south ridge (photographed in 1886), and noted the abrupt and uncomformable transition from the slate to the green schist. This occurs a little west from the crag, and in a lower place. There is no indication that either underlies or overlies, as the line of contact is on a nearly horizontal plane surface. The structure and bedding of the slate is interrupted somewhat obliquely by that of the schist, and shows plainly some kind of unconformity. This slate is siliceous and has all the banding of the jaspilyte, but is not colored. A little further north it is like jaspilyte. Indeed, it passes into the rock which is, or which becomes, or which embraces the ore.

Thence we went further west and after considerable search we found the low, bare, slaty knoll, consisting of fissile slate, which was mentioned in the report of **1886, in which was recorded a gradual passage from the clay slate to the chlorite slate of the region. We examined it to find sedimentary banding. While this banding is not, in the knoll, characteristically exhibited, yet there

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*Compare H. V. Winchell's report on this region, 17th report, pp. 88-9.

**Fifteenth report, p 267.

are some long, parallel, color-bands, about one-sixteenth to one-half inch wide, that appear to be due to sedimentary action. It is noteworthy that throughout this knoll of clay slate, generally no such bands are visible. This may be due to the shattered condition of the rock and the obliteration of an original structure by the process of acquiring the slatiness. Toward the east, the slate, followed along the strike, *evidently gets more and more siliceous*, till, after some intervals of non-observation due to drift and to brush, it is converted into jaspilyte, first passing through the condition of the slate crag described above. But there is in the midst of this slate, further east, a little greenish, coarse sericitic and quartzose slaty-rock (No. 1505), apparently alternating with the clayey slate, which may be the parallel of the schist seen to alternate with the jaspilyte rock, as at the railroad cut south of the Stone mine. This indicates that, as formerly supposed, there is a close alliance between the clay slate and the green schist, or at least *a schist* which cannot with any certainty *or satisfaction be distinguished from it*, and again an alliance that implies some community of origin and structure between all three of these schists. In following the strike along toward the east from this knoll we saw a bed about fourteen inches thick of such green schist (but rather darker and coarser grained), *imbedded in the jaspilyte**. The lack of sedimentary signs (*i. e.*, the general lack) caused me to query whether the eruptive green schists could become changed to argillyte, but on finding some, not very distinct, trace of bedding, and especially on seeing the argillyte bed change, in the direction of its strike, apparently first to siliceous slate and then to jaspilitic beds, the conclusion is found inevitable that the argillyte at least is an originally sedimentary rock.

But this leaves to still be accounted for the green (or gray when siliceous) schist which usually resembles closely the green schist which is supposed to be of originally eruptive origin, seen interbedded with the argillyte. On the suppositions that it is of identical genetic origin with the eruptive green schist, it may be supposed to have been brought there by slight eruptions at the time of the sedimentation of the argillyte, and that would rather require that all the supposed eruptive green schist which embraces the jaspilyte, originated in the same way, *i. e*, in a manner similar to the eruptive sheets of the Cupriferous, and is now interbedded in the great (Keewatin) formation, as schists, in the same manner. This would make the eruptive green schists date from the time of

*Compare Bulletin No. 6, where such a layer of silicious green schist is described on the north slope of the "north ridge," embraced in the contorted jaspilyte.

the Keewatin itself, and the green schists would be found to be, on a large scale, confórmable with the adjacent rock, instead of being of the nature of later overflows and uncomformable with it. The latter supposition was expressed in the 15th annual report.* I do not know that there is any necessary and known objection to that hypothesis. It would be necessary still to account for the rock having now the condition and structure of a schist and for its being sometimes the matrix for a multitude of fine pebbles of jaspilyte.

But it is not by any means certain yet that this gray schist (1505) is identical with, or can be found to grade into, the great body of green schist of the region, so that they can be embraced in the same general hypothesis.

We went over the south ridge at the Lee mine and west from there, and the following facts were noted:

1. In some places the jaspilyte is wonderfully brecciated over large areas, the same parts again cemented by the ferruginated granular silica, or by the same in a finer breccia, so that the general mass is as hard as the jaspilyte unbroken, and in this condition shows large glaciated areas.

2. When broken less minutely the cement is, in some other places, pure hematite, and when this has accumulated in large enough masses, filling pre-existing cavities whose forms it takes on, it is valuable as ore, and as such is the principal basis of the working of the Lee mine.

3. This accumulation of hematite, or re-cementation, took place before the deposition of any vitreous silica, or before any observable "silicification."

4. Chemical (*i. e.*, vitreous) silica was afterward deposited in openings and geodes in this hematite, and in veins crossing both the hematite and the jaspilyte, this being the last observable step.

5. I do not see hematite veins crossing chemical silica veins.

6. Hematite veins cross jaspilyte in all its forms, whether in breccia or as undisturbed strata in the jaspilyte.

7. Chemical silica veins and nodules occur latest and cross the hematite and also the jaspilyte.

This seems to show that there were two processes after the deposition of the original sediments forming the jaspilyte, viz., a ferruginization and a silicification, and that the former preceded. But, as already argued in the fifteenth report, the chalcedonic silica was not concerned in either of them, except that the rounded

*Page 221, 269, 322.

grains have become angular by deposition of interstitial silica. Samples 1506 show the relations of the chemical silica to the hematite, and 1507 show the brecciated jaspilyte cemented by a finer breccia of the same.

On Chester Peak (or Jasper Peak, so generally called at Tower), on the northwest side and shoulder, the jaspilyte dips north at an angle of about eighty degrees. It suddenly changes and dips west at seventy-five degrees, then as suddenly changes and dips east at seventy-five degrees. It then veers round on the apex of the hill so as to dip northeast at seventy degrees. In the easterly part, which is lower, the dip is north again. The hill is abrupt and short, but elongated about east and west. A stretch of drift, like a morainic ridge, rising about fifty feet, connects the hill with the "north ridge," in which are the mines of the Minnesota Iron Company; but there seems to be no rock-ridge uniting them. The "north ridge" dies out toward the east, although a series of low hills, making a lower range, can be seen to run along the south side of Vermilion lake and eastward. Toward the south the range of the Giant's hills can be seen from where it rises, on the south side of Birch lake to where they run out in the distance toward the west. They have openings and sudden elevations, but are without any notable peaks, the highest and apparently the most important hills being toward the southwest rather than south.

Numerous pits have been sunk by the iron company to the rock in the vicinity of this peak, and between it and the "north ridge". Some of them strike green schist, some a jaspilyte without ore, or a lean ore, and some of them reveal good ore. But in one of them, at the northwestern base of the peak, a black schist, soft and (carbonaceous?) holding balls of pyrite (1508) from a bullet's size to two and a half inches in diameter, was met in the bottom of the shaft. On the northern face of this hill are the green schists, seen at the mines, mixed and twisted with the jaspilyte. A deep drill hole on the south side of this hill afforded the diamond drill a core of porphyrel at several hundred feet below the surface, the hole sloping north.

Glaciated surfaces are seen nearly to the top, and a few boulders lie on the very top.

Some small veins in the brown jaspilyte consist of white chalcedonic silica (1509) crossing the jaspilyte banding. In the immediate vicinity are deposits of chemical silica. The existence of chalcedonic veins is a very rare occurrence, and has been observed, though doubtfully, but once before. Compare the fifteenth report, p. 324, and rock sample 1013. There must be some way to account

for these chalcedonic veins. They do not appear to have been formed by mechanical transposition of laminæ in or across the jas pilyte strata. They do not have any banding or crystallization like true veins. They form a network connecting a coarse (and in some places a fine) breccia of brown fine-laminated jasper. These are on the exposed upper surface of the glaciated apex of the knob. The silica is white, and appears to have the effect and disposition of vein matter but not its structure. This hill is in nw ¼ ne ¼ sec. 35, 62–15.

At Ely. The rock-cuts all the way from Tower to Ely, so far as seen from the train, are all in the green schist, or a green rock more massive than schist which imperceptibly takes its place, and at Ely is the rock which has there been described in the field-observations of 1886 (Fifteenth Report, pp. 325–26), and which extends from Ely to the shore of Shagawa (Long) lake, and really which goes also to Fall lake and there forms the falls. At the rail road cut at Ely it exhibits some new features, viz:

1. It is made up of rounded masses of itself, or rock like itself, some of them four feet across, and some not more than three inches.

2. The rock matter between the rounded masses is darker green than the rounded boulders, and squeezes among them in the same manner as green schists between jaspilyte boulders at Tower. It is also more apt to be a little schistose.

3. There is no bedding like sedimentation, but an angular coarse jointage like that of eruptive rock which has flowed in a broad sheet over the surface. The forms of these boulders are visible in the weathered surface, and their slickensided (and then darker) exteriors are shown on the face of the railroad cut.

4. The boulders are frequently amygdaloidal, calcite being the mineral enclosed; but the cavities are rendered conspicuous by the easy weathering out of the calcite.

5. There is a crust of somewhat darker rock that surrounds the interior of the boulders, and these cavities are most abundant in it; they are commonly in the form of tubes that cross this crust approximately at right angles, radiating as from the centre, though not reaching the centre. Transverse to these tubes this crust sometimes exhibits a dim linear structure that appears to be fluidal.

6. This green rock contains chalcedonic silica, disseminated all through it, and it seems to result from a change in the chemical silica

7. This green rock is of the same genetic nature, and the same in all its physical aspects, with the exception of such as can be referred to difference of weathering, as the Stuntz Island conglomer-

ate, but the enclosed boulders are less siliceous than the most of those in that conglomerate.

8. The rock that embraces these boulders is not usually, but is rarely, amygdaloidal. This is the rock which I designated, in this vicinity last year (1887), and before*, as modified graywcake, but it seems now never to have been in the form of graywacke.

No. 1510 is a sample of this green rock, showing the forms of two boulders, and the darker-green rock separating them.

No. 1511 contains amygdaloidal portions of some of the boulders, showing the tubes perpendicular to the surface, one specimen having a glaciated surface. (Compare Plate 1, Sixteenth Annual report).

No. 1512 has chalcedonic silica from veins and spots in the rock 1510.

No. 1513. Vein matter in No. 1510, similar to 1501 which is from the so-called gold-quartz vein at Eagle Nest lake.

In returning from Ely to Tower the conglomeratic (or agglomeratic) character of the green stone was more frequently noticed at the occasional cuts. The rock is angularly and cuboidally jointed in most of the cuts, with a light green color, weathers lighter, but in some cuts it is a schist with a slaty tendency in disintegration, and has doubtless been called sericitic schist in many places.

Southward from Tower this rock continues, as seen from the train, as far as nearly to the gneiss exposures that appertain to the northern flank of the Giant's range. It has been reported by H. V. Winchell** that there is no exposure of mica schist between its last exposure and the first of the gneiss. There is an unobserved interval, however, between the two amounting to about two miles in which there may still be a narrow belt of mica schist.

[NOTE. In the spring of 1890 a belt of mica-hornblende schist was exposed in some railroad cuts, a few miles north of the Giant's range syenite.]

Pokegama Falls and eastward to Griffin's camp. At the falls of Pokegama the dip of the quartzyte was carefully measured at several points, with the following results: Below the falls, S. 8° W. about 15 degrees; above the falls, S. 8° E. about 15 degrees; at the bluff, on the west side of the river, a sixth of a mile above the falls, S. 22° E. 8 degrees.

The rock is quartzyte, red superficially (from six to twelve inches) and gray within. The bluff above mentioned is 27 feet

*Fifteenth report, p. 326.

**Seventeenth report, p. 89.

high above the water, and the beds composing it seem to strike southeastward to the falls. Mr. Griffin says this rock runs under the river which is the outlet to Pokegama lake, and used to cause rapids at half a mile below the lake, in Sec. 23, T. 55-26. But now these rapids are covered by the setting back of the water into the lake from the Mississippi from the government dam, which is built just above the falls. He also says he thinks he saw once (as surveyor) an outcrop of it on Little Boy river, about in the line of strike from Pokegama falls. H. V. Winchell also reports having seen it on Little Boy river. Mr. Griffin also is authority for an outcrop of the same rock about eight miles southwest from Pokegama falls. In 1871 or 1872, as deputy surveyor, he also noted the same rock north from Sugar lake (two or three miles) in Sec. 6 or 31. This rock appears to be the Pewabic quartzyte, so named much further northeast on the southerly slopes of the Giant's range.

October 18, 1888. In the rain (there was a drizzling rain all the rest of the day) we went to the falls of Prairie river, first seeing the granite at the upper falls.

There is a large display here of gray gneiss, some of it being micaceous, and some of it having hornblendic, dark masses and belts cutting through it. In some rare places it is laminated in thin indistinct laminæ of mica and feldspathic sheets. Its dark belts and isolated masses recall the rock at Morton, on the Minnesota river (see another section of this year's report) and north of Vermilion lake, but there being so little of this it will not be correct to parallelize it with the mica-hornblende series. It is rather the extension of the Giant's range rocks, which are mostly without noticeable micaceous or dark hornblende laminations, and generally a more massive rock than the micaceous gneisses of the Vermilion series. At one point on the west bank of the river there is a rude horizontal, undulating stratification or bedding. On the east bank opposite this, however, the gneiss is conspicuously basaltically jointed It is probable, therefore, that the former may be due to weathering upon a spot where by a shearing pressure a local lamination had been superinduced. There are also in some places in the gneiss, thin alternations with a shining micaceous schist running about horizontal, such that the general aspect and average composition is quite different from the rock in general (see No. 1523). Red orthoclastic belts (1524) more coarsely crystalline, containing also coarse quartz crystals, run irregularly through the mass. In one spot a wedge of reddish rock, associated with chlorite, making a (protogine?) runs through it.

We do not see the contract of this gneiss with the overlying quartzyte. The latter is seen at the lower falls and while dipping in the main to the s. s. e. about 10 degrees (sometimes 12 degrees) it undulates in one or two synclinals. Along the top of one of the anticlinals can be seen a distinct fracture, opening somewhat upward, as the crest runs across the river.

Glacial marks here run S 10° E. (mag.) and Mr. Griffin says there is no magnetic variation here.

No. 1525 (a) represents an incipient or pseudo-amygdaloidal spottedness in this quartzyte, which may be allied to that lately described by Bailey at Pigeon Point.

No. 1526 shows another spottedness in this quartzyte, the rusty spots weathering out and making the surface pitted all over.

No. 1527. So far as can be seen then comes on toward the south (after an unexposed interval) a lot of siliceous and hematitic cherty beds, the hematite in some cases being fine, massive, nearly pure, and finely basaltically jointed. These beds are seen only about five feet in thickness, and the hematite is apparently not more than six inches. No. 1528 represents some of the rock about at the horizon of this hematite. No. 1529 somewhat above (in the beds). No. 1528. This shows a curious "streamed" mixture, and brecciated bed of chalcedonic silica, jasper and hematite, with vitreous glassy silica filling veins or former geodic elongated cavities that are embraced entirely in a casing of white chalcedonic silica. The highest part is represented by 1530, which has a very different aspect from 1529, being a coarser, evidently fragmental, rusty, siliceous, somewhat vesicular rock, but yet may be only a modified condition of 1529. It has pure hematitic sheets and lumps, and is, in general, bedded, and dips conformably with the quartzyte below, in beds fron six to ten inches thick. It is mainly a felsyte with hematite, some of the beds having the bloodstone distribution seen in some at the east end of Gunflint lake. Some of the quartzyte that underlies is conglomeritic (1532) in patches, but it is not seen so in any continued layers.

In making the trip from Grand Rapids to Griffin's camp (see sketch-map, fig. 1, p 16), we traveled eighteen miles over an execrable road in an autumn snow storm which not only kept our clothing wet but loaded every bush with dripping snow and water. As we had been in the rain the greater part of the previous day, and returned the following day in a snow storm of the same kind but somewhat cooler air, we found the three days productive of results not entirely geologic.

Fig. 1.

The trip was very useful in a geological sense, but it cannot be said to have afforded sufficient evidence to answer the question of the true relation of the Pewabic quartzyte to the black slate of the Animikie. So far as the evidence goes, *unless there be two great quartzytes*, it seems to indicate that the Pewabic quartzyte overlies the black slate, although it is next in contact with or adjoining the granite all along the south side of the Giant's range and as far west as to Pokegama falls, at the latter place the quartzyte being separated from the gneiss by an unexposed interval of unknown strata, which is presumed to be occupied by the Animike slates proper. This evidence consists in the existence of the red soft shale (1533) above the quartzyte (1534), This shale is apparently the equivalent of the red shale which have been penetrated in some deep wells in the central part of the state and found to overlie the quartzyte (the New Ulm quartzyte), and also perhaps of the red shale seen at Black River Falls, Wisconsin, on the south side of the "Tilden mound," to which it bears a strong resemblance, making thus the

ore at Black River Falls the equivalent of that in the Animike (Huronian proper) in Minnesota, to which in its lithology and general character it has a close resemblance, as well as in its near proximity to a corresponding range of gneissic hills. It also confirms the opinion, elsewhere expressed by the writer, that the Gogebic ore is probably in the beds which, on the south shore, represent the Animike of the north shore, instead of the beds that contain the ore deposits at Vermilion lake. The structure here is represented by figure 2, showing an ideal section running north and south at Griffin's camp. The horizon is therefore very near that of the works of Mallmann, and of the mines in the Gogebic region.

There is yet one troublesome unexplained fact, which does not fall into place in accord with the idea that there is but one quartzyte and that it overlies the black slate unconformably, viz: The ore mines on the Gogebic range seem all to have an important granular gray quartzyte underlying them, and, according to all I know, a black slate lying to the north of them and probably stratigraphically above the ore beds, these black slates being supposed to be the Animike. If that quartzyte be the equivalent of the Pewabic quartzyte it certainly

Fig. 2.

runs below the iron horizon, and the Animikie iron, the supposed equivalent of the Gogebic iron strata, should be sought

for toward the south from the strike of the Pewabic quartzyte in Minnesota. As there are outcrops of slates and quartzytes, of the Animike series, along south from the strike of the Pewabic quartzyte it is also legitimate to infer in the absence of facts demonstrating to the contrary, that in Minnesota also the main mass of the Animikie, and hence also the horizon of the Gogebic ore, lies conformably above the Pewabic quartzyte, and may be found to the south of the strike of the quartzyte. In all the reports and inferences that have been published by the writer the Pewabic quartzyte has been made the parallel of the great quartzyte that overlies the Animikie unconformably, but it is possible that it runs below it conformably. Its age in either case is that of the great gabbro flood, with which it is interbedded at points further northeast.

Specimens from Griffin's camp, ne¼, sec. 22, 56-24, No. 1533, red shale, 8 feet; No. 1534, iron bearing rock, somewhat siliceous, ore-sheets broken and irregular, hematite; No. 1535, same as 1534, pit No. 2. but reached at 15 feet below the surface; No. 1536, same as 1534, 11 feet below the surface. No. 1537, slaty ore, rather ow grade, (47 p. c.) nw¼, nw¼, sec. 21, 56-24. Mr. Griffin says that in sec. 21 he knows that the rock 1537, lies to the south from the rock 1535 and 1536, in outcrop in the same section. He also says that at three or four miles south from his camp fragments of black slate are abundant in the drift, indicating black slate lying above the rock seen at his camp.

Where the road crosses the morainic belt (see the sketch map, Fig. 1,) between towns XXIV and XXV, the hills are very conspicuous. It appears that the morainic belt coincides, in general, with the strike of the quartzyte, a fact which has been noticed before in Minnesota (and in Ohio, in case of a strike of the limestone as in Delaware county), and it is very likely that the existence of the latter had a powerful influence in determining the southward limit of the drift-laden ice.

That this range of iron ore is independent of and quite different from that at Vermilion lake, which is in the Keewatin schists, is shown, not only by the general geology and geography, and the difference in the manner of occurrence, as well as in the ores themselves, but by the fact that the line of strike of the Keewatin ore belt from Tower westward is found to cross the country about thirty miles further north. It has been discovered at several points, where it affords very encouraging outcrops, and samples of first-class magnetite have been exhibited by those who have visited the region. Mr. John Beckfelt, postmester at Grand

Rapids, ** has manifested an intelligent interest in this more northern iron region, and from the samples in his possession the following were obtained: No. 1538, magnetic iron ore, sec. 23, 60, 23; No. 1539, rock associated with 1538. This is magnetic and siliceous, black, fine grained, apparently a magnetic jaspilyte. * This is described as standing vertical in the midst of vertical green schists. Charles Kearney, Grand Rapids, owns an iron location on sec. 27, 60-23, and — Fleck on sec. 23, 60-23; other owners are reported to be Lawrence Welsh, James Gill, Eli Signal, William Wynn, Al. Tory, J. H. Hennessy and — Knutson.

According to Mr. Griffin, there is an outcrop of "granite" at a point about ten miles south of Leech lake, the exact position of which he could not give. This indicates the strike of the Giant's range granite.

Gold in the Keewatin schists in northern Minnesota. It is well known that about twenty years ago, a gold excitement sprung up in Minnesota, centering on Vermilion lake.† Mr. H. H. Eames, the state geologist at that time, was largely instrumental in promoting the popular interest in that region, and in the reputed discovery of gold. The excitement subsided soon, and ever since then there has been very little said on the subject. But it appears now that there was some basis of fact underlying the excitement, and that possibly in the future the interest that subsided in 1866 may be partially revived. Several assays of auriferous quartz were published by Mr. Eames in his reports, some performed by J. R. Eckfelt, assayer of the U. S. mint at Philadelphia, others by professor E. Dent, New York, and by himself, which afforded gold amounting from twenty to thirty dollars per ton of the ore, with three or four dollars per ton of silver. This came from some of the workings about Vermilion lake.

In 1887, the writer visited the Marquette iron region in Michigan, and the Ropes gold mine northwest from Ishpeming.‖ He was at once impressed with the resemblance between the gold-bearing rocks seen all the way between Deer lake, near Ishpeming, and the Ropes mine and the rocks of the Keewatin, in northern Minnesota,‡ and in all subsequent study, involving this question,

** Mr. Beckfelt also showed samples of lignite found "up the Mississippi river," say about Winnibigoshish lake. He also says it is reported to be found all about the shores of lake Winnibigoshish, in form of "float" pieces. He also states that he has seen pieces found " up the Prairie river."

* The occurrence of magnetic ore in the Keewatin, near Ely, as well as at Tower, is described in Bulletin No. 6.

†Compare the report of H. H. Eames on "The metalliferous region bordering on lake Superior." printed in 1866.

‖Sixteenth annual report, pp. 48-49.

‡Seventeenth annual report, pp. 42-43.

he has placed the two localities provisionally in the same stratigraphic position. This parallelism at once recalled the early reports of finding gold at Vermilion lake, and aroused a suspicion that gold would be proved to exist in the quartz leads in the Keewatin, in Minnesota.

In 1878, this region came again under examination by the state survey in a rapid reconnoissance, made by the writer, along the international boundary to Vermilion lake, and thence to the St. Louis river, and the principal "locations" were visited. The small specimens collected from the dump heaps were as large as the means of transportation would permit, and of course feebly illustrate what may have been the contents of the veins that were explored by the various owners in 1866. The samples are numbered 395–400, and 423, 428.*

Prof. A. H. Chester again examined these gold-mining locations, and states in his report that "Specimens were collected from many quartz veins, on some of which mines were formerly located, and all were carefully assayed. No true iron pyrites was found, but all was of that form known as pyrohotine or magnetic pyrites. Among the many samples of pyrites, from all parts of the country, assayed for gold at the laboratory of Hamilton college, not one containing magnetic pyrites has shown any gold, and so-called gold mines have been condemned at once when the character of the pyrites was recognized, subsequent assay always corroborating the opinion. It was, therefore, not a matter of surprise that these 'gold ores' did not contain any gold."‡

In 1886 Dr. A. Winchell examined the town in which is situated a prominent white quartz vein in which it was reported gold and silver had been found, and his collected samples at this point are numbered (of his series) 48-53.** He says: "Many quartz veins run through the whole formation. Rock 52 is a sample, containing hematitic stains, very much, indeed, as in some argentiferous[auriferous?] quartz. Other quartz veins are pervaded by pyrites in abundance, as shown in rock 53. In some cases a mass half the size of one's head is pure pyrites. The pyrites and quartz are sometimes seen to be intersected by minute, sinuous veins of a dark, lustrous iridescent mineral resembling peacock ore of copper. These are the glittering minerals which sustained, not without some reason, the hopes of the adventurers." At that time this spot was owned by a man, since deceased, named John Leienderker, who had sunk a shallow shaft in 1885.

*Ninth annual report, pp. 98-103.
‡ Eleventh annual report, p. 166.
** Fifteenth report, p. 32.

In 1888, in making some observations on the iron working of John Mallmann, about two miles south of the Giant's range, as reported above, the writer met Mr. Leienderker at Mallman's camp, and obtained from him a small piece of the quartz containing pyrites from his "gold mine" on Eagle Nest lake. Sec. 34, T. 62-14.

Some assays have since been made, viz:

Samples of pyritiferous quartz obtained by A. Winchell, from Leienderker's shaft, with the following result, assayed by Frank C. Smith, Ann Arbor, Mich.

A. Winchell's numbers 49 and 51, gave no trace of gold.

A. Winchell's number 53, gave one-twentieth of an ounce of gold per ton of 2,000 pounds, or $1.00 per ton.

Sample of pyritiferous quartz obtained by the writer from Mr. Leienderker; assayed by Prof. J. A. Dodge, Chem. Series, 212. Survey No. 1501. "Using one-half ounce of the ore, by fire assay, I find a trace of gold and no silver. The amount of gold is too small to be weighed from that quantity of ore; I should estimate it at not more than one-fortieth Troy ounce per ton."

All the samples from the various "locations" about Vermilion lake obtained by the writer in 1878, * assayed as one sample by Prof. C. F. Sidener, Chem. Series, 213, gave no gold nor silver.

The vein at Eagle Nest lake is said to be about 12 feet wide and to carry much pyrites throughout its width. The pyrite in the sample obtained from Mr. Leienderker is not magnetic in fine powder. It has a light brassy color and rectangular, apparently cuboidal, crystallization, which seem to indicate true pyrite. That which Prof. Chester examined was magnetic pyrite which is rarely if ever auriferous, and was at once condemned by him. There is a large amount of magnetic pyrite near the base of the Animike formation at the west end of Gunflint lake, associated with the magnetic ore of the Animike, which is of the same range and age as that investigated by Prof. Chester on the Mesabi range, and it is quite likely that the magnetic pyrite examined by him was obtained in that group of rocks. That has a different aspect and color from the pyrite at Eagle Nest lake, being a copper-steel gray, and also is much softer.

It appears from the foregoing considerations, and the facts that are known, that not only is there no *a priori* obstacle to the expectation of gold in the quartz leads of the Keewatin, but that there is some positive basis of fact to show that it exists there in

* Ninth annual report, pp. 98-103.

quantity sufficient, in some †cases, to make a valuable low grade ore that could be profitably mined by the same methods as those employed in the Black Hills, and at the Ropes mine in Michigan.

The Crystalline Rocks of the Minnesota Valley.

In June 1888 some observations were made about Redwood Falls. At Frazer's quarry, in Honner, (N. Redwood P. O.) which is on the south side of the Minnesota, but on the northwest side of the Redwood, in the bottom lands of the Minnesota river, can be seen gneiss, some of which is prevailingly red on weathered exposures, but on quarrying deeply—and some without being quarried—is gray. This rock is a gneiss, through and through, having a "rift" which is strongly marked, and generally evident in difference of colors and in micaceous belts, the alternations being black, quartzose, feldspathic, reddish, &c. There are some places that show up as a massive, gray gneiss, without much banding, but the whole rock is generally quite banded. Across these forms run granulyte veins, and coincident with the gneissic bands are other orthoclastic belts, some of them plainly fading out into the gray gneiss, and some being distinctly separate for many feet. These are either of chemical deposition entirely, (as when filling transverse fissures) or are produced by slow chemical metamorphism from the original sediments. In two instances one of these veins, about ¾ in. wide, running transverse to the grain of the gneiss, split in the center of the vein, and one-half of it adhered to one block, and the other to the other block, when forced by the operations of the mine. This splitting ran about six feet, and showed, when cleared off, a surface 16 in. by 6 ft., and at a distance I took it at first for a vein 16 in. wide because viewed from that direction. This vein matter was coarse red granulyte. Other similar veins when viewed on the broken edge showed a distinct *central plane of union* between the growing accumulations on the opposite side

†Capt. Gibbons, in test-pitting for iron in 63-11, is reported to have found a nugget of gold valued at about four dollars, and Mr. J. G. Emery affirms that in the quartz veins in the greenstone on the southern slope of the Twin peaks south of Ogishkemuncie lake he has very frequently obtained gold. It might also here be recorded that according Mr. Emery, who showed me a sample, a finely granular graphite occurs on lot 9, se ¼ sec. 18, 64-6, (east of Frazer lake). He describes it as surrounded and overlain by gabbro. At a mile further west, and a little north, it shows on the surface in a vein ten feet wide; and pieces as large as a half bushel lie about, as if thrown out by the frost. It is also found on the portage trail (a little north of the trail) from the east end of Frazer lake to the lake next toward the southeast. Considerable iron ore is reported by him in the greenstone, in the north parts of secs. 2 and 3, 64-6, *i e*, in the region of the Twin mountains.

of the original fissure, just as in common mineral veins, thus: Fig. 3. Such a plane would be a plane of weakness, along which in quarrying, the rock would be likely to part.

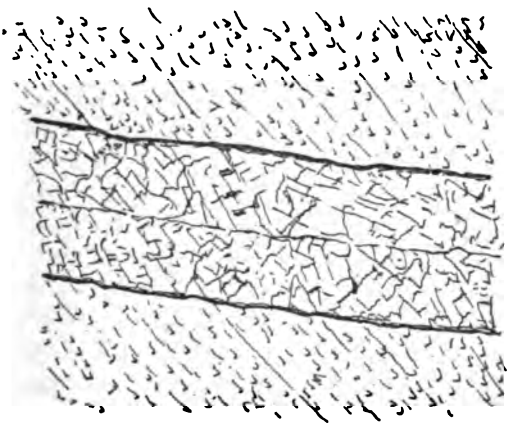


Fig. 3. Layered vein of Granulyte.

At Morton, a few miles below Redwood Falls, situated in the valley of the Minnesota river, Saulspaugh has recently opened extensive quarries in the "granite." Here the rock is mainly a gray contorted gneiss, but it has, in all the usual forms, much reddish feldspar supposed to be othoclase. Veins of granulyte cut the gneissic structure. One was 14 inches wide and was banded in the same manner as illustrated by fig. 3 above, except that its course was nearly perpendicular to the gneissic rift, and it showed, further, a banded alternation of quartz and feldspar, as illustrated by fig. 4 sketched on the spot.

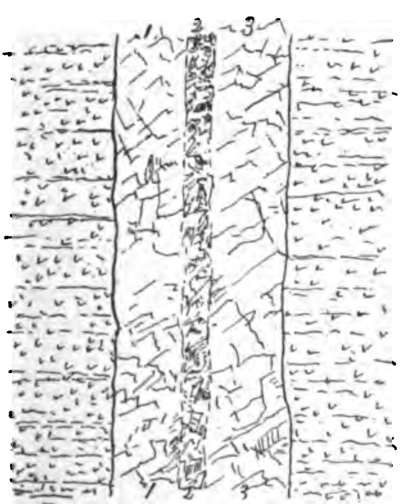


Fig. 4. Vein of Banded Granulyte and Amethystine Quartz.

Explanation of Fig. 4.

No. 1. Coarse orthoclase, with little quartz.

No. 2. Coarse crystals of quartz, somewhat amethystine.

No. 3. Same as No. 1.

This shows a true vein structure, and a chemical origin for the "dyke." The figure shows the planes separating the quartz from the orthoclase rather more abrupt and straight than they are in nature. Along the line of contact some of the orthoclase crystals penetrate within the quartz zone, and there are a few quartz crystals disseminated through the orthoclase. But, as a whole, the central band of amethystine quartz is distinct and constant.

Another remarkable feature in the Morton quarries, where there has been more work done than in any other granite quarries in the state, and from which they have sent rock for street curbing to Duluth, is the beautiful contortion of the gneissic structure, which on being broken, and especially when cut-hammered, makes a striping resembling that seen on some fancy marbles.

And yet another feature, which allies this belt with the transition series at the northwest end of Vermilion lake, is the irregular mixing of the "mica schist," or "black rock," with the gneissic lighter-colored rock. These so-called mica schists appear as isolated masses, one as large as ten feet across, but usually only a few inches in diameter, like boulders in the midst of the gneiss. In one conspicuous instance, seen on a freshly cut block of gneiss, the laminations of the gneiss were seen to shape themselves about the black mass. In many other instances the black patches are changed in shape, apparently by some shearing pressure incident to the whole formation. They are elongated and bent and strung out like hooks and lenticular bands, in conformity with the direction of the general trends of the gneissic contortions.

While these black patches appear (now) to be largely micaceous and of the same nature as the micaceous element in the gneiss, yet there is noticeable a difference. They seem to be of changed hornblende or hornblendic rock (1519.) The "black rock" in one limited space was seen to comprise at least half of the whole, and it seemed to be the same ingredient as the black element in the gneiss—at least so far as its distribution and relations could be seen to show anything of its origin. This "black rock" should not be confounded with another "black rock" which in the form of a conspicuous more recent dyke cuts across the hill composed of gneiss.

The general similarity of this quarry to the mixed condition of the mica schist and syenite in the northwest part of Vermilion lake, where the Vermilion series fades out into the gneiss proper, of the Laurentian, is forcibly impressed on the mind of any one who is familiar with the latter. The transition in the Minnesota valley, however, seems to occupy a wide belt, as it extends at least from Redwood to Morton—and indeed to occupy nearly the whole valley.

In town 111–38 (unorganized), of Redwood county, sec. 12, is a glaciated granite knob, the striæ running S. about 45° E. This is a dome of gray contorted gneiss, rising about twelve feet. Its visible extent is about 200 feet, and 90 feet across. Its elongation is NW. and SE. It is a good rock for heavy quarrying, as it is not

much jointed. It is heavily bedded by a series of overlying layers that dip gently toward the south, so that the steep side of the knob is on the north slope. The country round about it is wild, unoccupied prairie, smoothly rolling.

This rock shows no red feldspar, in that respect being somewhat more like the Honner quarry than the gneiss at Morton. The top is somewhat below the average level of the country, and has been uncovered by the removal, by some means, of the drift cover. The field can be plowed right up to the rock on all sides.—Sample 1520.

In making this trip a new sort of boulder was seen in many places—a white granular quartzyte, some of them two feet across. They show a plain sedimentary structure, and are rather fine-grained. They are hauled with other boulders into piles from the fields. They look like the usual "Winnipeg" limestone, of which not a piece was observed on the trip, although they do occur about the mouth of Crow creek.

Re-examination of Lignitic beds about Redwood Falls. In company with Mr. Park Worden, Capt. Dunnington and Mr. Terrill, of Redwood Falls, a number of workings in lignite beds in the vicinity were examined, particularly in the region of the valley of Crow creek. One of these was the very spot that I visited 15 years ago, now caved in, and nearly lost to sight. Another was visited with Mr. Peabody at the identical spot where Grant and Brousseau tried to get coal about 20 years before. None of these reveal anything new, nor give any reason to vary from the judgment and descriptions published in the second annual report, respecting their geological age and prospective economic value.

At Mr. Farrington's, on the bluff of the Minnesota near Crow creek, the lignite lies on the decayed gneiss, or on a somewhat stratified and re-arranged condition of it, due to the Cretaceous ocean. There is no conglomerate at the bottom—only this kaolinic material.

III.

Record of some Field Observations made in 1889.

Duluth. On the "Weller road," about a mile and a half from lake Superior (at Duluth) and about two miles, by the road, from the business part of the city, is the spot that has been referred to *before as showing considerable amounts of red rock in the hills.

*Survey samples of N. H. Winchell, Nos. 1B, 46.
Compare also Proceedings of the American Association for the Advancement of Science. 1881. Cincinnati meeting, *Typical thin sections of the Cupriferous rocks in Minn*

There is not so much of it as I had thought. It is very certainly the same rock, and has the same relation to the gabbro as that seen at Duluth and mingled with the gabbro at Rice's point. It is here in a scattered blotch, and in thin veins, in a fine porphyritic, gabbroloid rock—which last is like much seen in the city and environs of Duluth, but not so perfectly and coarsely crystalline as the Rice point rock. While the gabbro is quite different from the typical gabbro at Rice's point, it is essentially the same rock and of about the same age. Indeed it is almost possible to trace it continuously from one place to the other along the hill range that connects the two places. No. 1540 shows the gray porphyritic gabbro with a fine magma. No. 1541 shows contact of the red rock on the gray rock, 1540. No. 1542 is the crystalline red rock, with some light green spots. No. 1543 is chalcedonic quartz from this gabbro, as described below.

A very interesting observation is made in connection with this modified gabbro. On the weathered surface, where it also presents other irregularities of structure, resembling coarse amygdaloid, are seen white spots of silica. These spots are sometimes vitreous and glistening, as if of chemically deposited quartz, and in some central cavities quartz crystals form a drusy coating. But in other places this pure vitreous white quartz becomes granular, there being a gradual passage from one structure to the other, the granular increasing in distinctness and ease of disintegration toward a weathered angle, or toward the surface. Very rarely, small, subtranslucent areas as large as a wheat grain, or larger, can be seen, on the disintegration of the vitreous portions, which do not disintegrate, resembling amorphous or chalcedonic silica. The disintegrated granular portions, however, are not uniformly fine, and, in general, those portions are all coarser than the fine granular silica of the so-called chalcedonic silica of the iron mines. This observation shows:—*That the granular structure seen in silica, does not prove necessarily that the silica was of sedimentary or clastic origin,* since this is plainly the result of long weathering of chemical selica in these exposed cliffs.

These quartz masses do not show plainly a banded agate-like structure like the agates seen at Agate bay, or Gooseberry river, but in some of them there is a narrow band of harder, somewhat reddish, siliceous rock that surrounds them and forms an enclosing ridge that rises above the general surface. They vary in size from a pea to eight inches long, and while not very sharply angular, are not of the shapes of usual amygdules. Some of them have little cavities of irregular shapes in which small quartz crystals are seen

projecting, and in others the white vitreous quartz is replaced, in marginal patches, or even in larger table-like protrusions, by a milky, opaque quartz, as mentioned above. Taken altogether it seems very likely that these quartz modules are indigenous in this gabbro-like rock, and are not of the nature of foreign or transported masses, but have originated in the gabbro by secretion, in a manner similar to the chalcedonic agates in the trap at the mouth of Gooseberry river (519).

At the Iron Mines at Tower. The designations of the various "mines" have been changed since the ownership changed. They are now known by number, viz:

No. 1 is what was known, and designated in our former reports as the Stuntz mine. It is the most easterly of those on the southern slope of the "north range."

No. 2 is what was formerly known as East Stone mine.
No. 3 is what was formerly known as Stone mine.
No. 4 is what was formerly known as Stone mine.
No. 5 is what was formerly known as East Ely mine.
No. 6 is what was formerly known as West Ely mine.
No. 7 is a pit on the former Tower mine.
No. 8 is what was formerly known as the East Tower mine.
No. 9 is what was formerly known as the West Tower mine.
No. 10 is what was formerly known as the Lee mine.
No. 11 is what was formerly known as the East Lee mine.
No. 12 is what was formerly included in the Breitung mine.
No. 13 is what was formerly included in the West Breitung mine.

Under the direction of Mr. H. A. Wilcox a systematic probing of the region has been carried on by diamond drill. This has resulted in the discovery of the existence of ore in some places not known before, and particularly near Tower in the "south ridge" or Lee mine. Some of the particulars of this drilling have been supplied to the survey. Indeed, through the courtesy of Mr. Geo. C. Stone, and of Supt. Bacon, every part of the mine, and all the records whether of drilling, assaying, mapping, shipping and grading, pertaining to the operation of the company, were thrown open to the writer for the use that might be wished for the purposes of the survey. Much assistance was afforded in making this re-examination, by the co-operation of the officers and the mining captains of the Minnesota Iron Company, and especially by the records of the drilling and some chemical analyses, the former by Mr. H. A. Wilcox and the latter by — Waters. Most of this detailed information is to be found in the special report on the iron ores of the state—

Bulletin No. 6, accompanying this report, but published separately. Subsequently the same courtesy was extended to the survey by the superintendent and other officers of the mines at Ely.

The purpose of this more detailed re-survey was to arrive, as nearly as might be, at a final conclusion, based on facts observed in the field, touching the question of the origin of the iron ore; and while that was a primary purpose, it was intended also to obtain more details of the actual manner of occurrence of the ores, the operation of the mines, and all the statistics that would be needed in making a full presentation of the iron ores in published form.

These observations were made in company with, and by the assistance of Mr. Horace V. Winchell who had previously examined many iron localities in the state, and had been exclusively at work on the iron deposits for about a year, and who was familiar with all the theories that had been proposed, and the obstacles that they met with. We subsequently published in *The American Geologist,** a summary and preliminary statement of the probable result of the investigation, so far as it related to the origin of the ore itself, and the same view is presented again, more fully, with many facts that sustain it, in another part of this report.

At this place but little more will be given than the connected thread of successive field observation, with references to the illustrative rock samples, and some of the steps in the argument.

At the Lee mine, rock sample 1546. Here we collected some of the quartz crystals lining vugs in the dense hematite. These have not the clouded "chalcedonic" appearance of crystals formed rapidly, or of rapid chemical accumulation without crystalization, such as seen in the quartz in the jaspilyte. This kind of quartz in the ores of the district has frequently been described in the reports, and it has been supposed to have had a later origin than the jaspilitic quartz.

In the dump at the Lee mine (No. 10 as above,) is seen a reddish, earthy-looking jaspilyte, beautifully streaked as with sedimentary banding—No. 1547. It contains much pyrites, which is in bands and streaks coincident with the banding, this being apparently the form taken by the ore when accumulated under circumstances that gave the jaspilyte this earthy character. While this pyrite is disseminated minutely through the whole of this, yet in larger quantity it frequents certain bands. It is noticed that these bands cease abruptly along one side, when viewed on the

*American Geologist, vol. iv. p. 291. *On a possible chemical origin of the iron ore of th Keewatin in Minnesota.*

broken edge of the sedimentation, as if the conditions allowing its formation were wholly and suddenly changed in that direction. But on the other margin the pyritiferous bands fade out gradually in the midst of the other rock. This is the first instance in which any such variation, indicating an upper and a lower side to the jaspilyte in the process of formation, has been observed. It is probable that the line along which the abrupt change is introduced was the lower side of the pyrite band, and if the position of this impure jaspilyte within the mine, with respect to the strike of the ore mass, could be ascertained, it would furnish a key to the stratigraphic order of super-position of strata of the region–a desideratum which has not yet been supplied by actual observation, though it has been hypothetically deduced from a general view of the whole region. The principal pyritic streaks are about a quarter of an inch apart, but there are intermediate variations that also produce streaks, and on one side of the specimen collected the principal streaks are about three quarters of an inch apart, and somewhat undulating.

In other pieces this impure streaked jaspilyte appears as a pyritiferous impure hematite, and in others, still, the pyritiferous character is generally disseminated in the breccia of hematite and earthy jaspilyte. In larger cubes the pyrites is seen in a sort of soft greenstone.

1548. Breccia, a somewhat stratiform mass of fine pieces of red jasper, hematite, jaspilyte, quartz.

1549. Crystals that seem to be chalcopyrite, colored sometimes blue like erubescite (?) or bornite, Lee mine.

[On further examination these blue crystalline grains seem to be hematite tarnished.]

1550. Finely banded, whitish jaspilyte, part of a breccia, Lee mine.

1551. Hard hematite, with conspicuous included crystalline masses that appear to be chalcopyrite.

Going in the pit of the Lee mine, which is now 100 feet in depth, under the direction of the foreman (because we inquired as to the place of rock No. 1547 in the mine), we find the succession across the Lee mine to be as follows:

In fig. 5, which is an outline plan of No. 10, formerly known as the Lee mine, the star (*) indicates where the bedded rock, No. 1547, was found. Next north of it is breccia, with green stone material, with considerable pyrite and with the well-known white kaolinic, white substance. In the kaolinic material are ser-

icitic, but rather hard and coarse-grained pebbles. There is an abrupt transition from fine, hard hematite to the rock 1547, but the contact, which can, with some difficulty, be traced out on the face of the wall, is tortuous and oblique. In the kaolinic material are also rounded pebbles of No. 1547. The general order of succession, across the mine, is thus, from north to south.

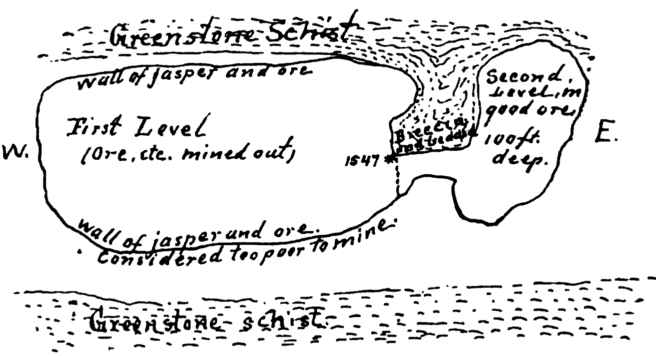


Fig. 5. Outline plan of the Lee mine.

1. Greenstone of the country, a chloritic schist, north side of the mine.
2. Breccia of greenstone, impure jaspilyte (rock 1547) and iron ore, with much pyrite.
3. Red, impure, sedimentary banded jaspilyte, somewhat resembling, in some places, a red shale, though it is always too hard and too heavy to be called shale. It is different from the well-known jaspilyte, as it shows no distinct chalcedonic silica, and only occasionally any distinct lines of hematite. It is not an important deposit, as to its amount, but apparently quite so as to its nature and origin, and its possible relation to the pure jaspilyte.
4. Fine, hard hematite, pure.
5. Main mass of ore; at its narrowest place about five feet wide, at the present face of the slope.
6. Jaspilyte, too poor to mine.
7. Greenstone schist, on the south side of the mine.

It seems as if the succession of formation progressed from the south to the north (or from No. 7 to No. 1), the impure jasper, No. 3 (or red shale) being formed by wash from No. 4, but rendered soft and impure by influx of materials from No. 7, or some other adjacent greenstone, and accumulated only in favorable nooks, followed by another greenstone (or schist), the latter serving, not only to break up and embrace in form of a breccia all the foregoing (Nos. 7 to 3), some of the inclusions being from the impure jaspilyte, some from the iron ore, and some from the jasper further south—but to contravene all the forces, whatever they were, that deposited the jaspilyte, and to substitute its own products entirely,

with little or no modification, for the hematite and silica that had been deposited immediately before. If this schist (No. 1) were an undoubted, massive, homogeneous, non-clastic rock, it would be necessary to infer that the jaspilyte had been covered by a diabase overflow, and that in the bottom of the lava the materials of all the former strata had been involved in a brecciated condition. The occurrence of this breccia on the north side of the main jaspilyte mass, however, is not conclusive evidence of the later date of the origin of the northern side of the Lee mine, since there are jaspilyte masses in the green schist further north still, and some of them, when they were entire and continuous in one mass, may have supplied the material for the breccia, allowing the order of formation to have been from north to south.

Not far from Lee mine, by the old roadside leading to the Breitung mine and to the "location," on the top of the main hill, a large boulder was found of the Stuntz conglomerate, and its examination afforded some interesting facts.

1. This boulder contains pebbles of chalcedonic quartz (1552), some of them being several inches across.

2. It contains pebbles of gray, quartzose felsyte (1553 and 1554).

3. In these felsyte pebbles, which themselves are older than the boulder in which they are embraced, are rounded vitreous quartz pebbles which do not indicate any granular structure like the so-called chalcedonic silica.

4. Some of the pebbles of 1553, represented also by 1556, seem to exhibit an imperfect porphyritic structure, approaching that of "porphyrel" at Kekekebic lake, which they also resemble in nearly all other respects. This may point to some relationship between the Keewatin schists represented by the Stuntz conglomerate, and the porphyrel. The rocks, however, need a closer comparison.

The important result of this observation, however, is in the bearing it has on the nature of the granular structure of the jaspilitic silica. It has been presumed by some that the jaspilitic silica is granulated because of incipient decay, in the manner that the geodic silica in the gabbro near Duluth becomes granular. Not to mention here the evident difference between the granulation that is due to decay and that which is seen in the chalcedonic silica of the iron mines, it is sufficient to call attention to the perfectly intact vitreous condition of the quartz *pebbles within the pebbles* in this boulder, even when by fracture they have been brought to the surface of the boulder, and the perfectly characteristic chalcedonic granulation seen in the younger pebble of jaspilitic silica, No.

1552 above. That which is non-granular in this boulder is necessarily older, and has suffered more revolution of physical exposure, than that which is granular, for it is embraced within a smaller pebble, whereas the granular-silica pebbles are not so embraced. The granular silica pebbles are of the age (so far as respects the formation of this boulder) of the gray quartzose felsyte which incloses the non-granular silica pebbles. The inference is inevitable that it cannot be exposure and incipient decay which causes the granular condition of the jaspilitic silica.

We visited again the place that has been so many times referred to south of the Stone mine (pits Nos. 2 and 3) where, at the railroad cut, there is such a curious mingling of the green schist of the region with jaspilyte. I visited this cut with M. E. Wadsworth in 1886, to call his attention to the sedimentary interbedding of the schist and jaspilyte. There is a thin-leaved interstratification, and the jaspilyte is genuine, as such, not in "compound grains" as I had surmised. Cutting all this chalcedonic quartz are distinctly different veins of glassy quartz, of chemical origin, which has to be kept separate from the jaspilyte, some of them being six inches wide, and others not more than one-fourth of an inch—also geodic masses of the same.

Not only is the chalcedonic silica here interbedded, in lenticular sheets of the extent of one to three feet, (but frequently of less extent) but also there are small pieces disseminated through the schist, from the size of a pin-head to that of a man's fist, and also large masses having a red and purple color, placed somewhat irregularly in the schist.

There is also a siliceous base in the schist, which has this same chalcedonic grain, and some layers, (lenticular still) of a hard green rock, apparently more charged with this same silica.

As to this manner of occurrence of jaspilyte, I cannot make it consistent with any eruptive hypothesis—nor yet with sedimentary. The green schist is not here clearly of sedimentary structure, though there are variations in it to a more firm and siliceous character, that may be attributed to sedimentary accumulation. It appears to be best explained by supposing a combination of eruptive and aqueous agencies.

South of the Breitung opening, near the west end of the so-called "north ridge," runs a narrow streak of ore, about east and west, and since I saw it last it has been worked some. Westwardly it suddenly ceases, and a swampy patch supervenes, so far as can be

seen in that direction. Toward the east it rises in the south slope of the main ridge, but as it is under drift deposits it cannot be traced but a short distance, and especially since where the work ceases in that direction it became rather narrow—say four feet, and seemed not to contain much ore. The structure of the green schists here dips northerly at 85° from the horizon, and the belt of iron and jasper oscillates in the schists on one and the other side of a right line.

This iron deposit is not first-class, but often pyritiferous, spongy and irregular, and apparently somewhat manganesic. The schists, at the spot where this belt crosses the road to the Breitung mine (No. 12), show a granular graywacke or sedimentary structure and origin, but not generally.

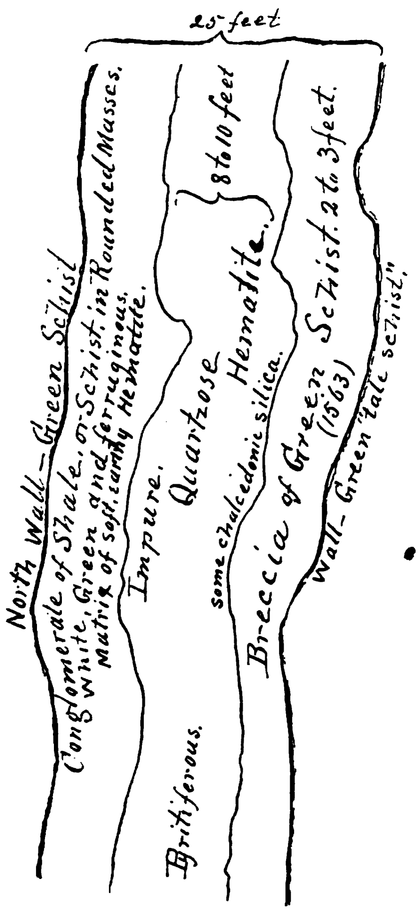


Fig. No. 6.
North and south section across ore pit near the Breitung, in the narrow ore belt.

On inspecting the order of changes in the stratification across this narrow iron belt where exposed in the cut at the eastern end of one of these small pits, a north and south section is obtained.

The narrow ore-belt, a section of which is seen in figure six, is very largely "derived" from some other larger bed. It is not exactly like the regular jaspilyte ore of the north ridge, inasmuch as it is fragmental and consists of rounded masses of both jaspilyte and green schist. This is conspicuously so in the breccia on the southern side and in the conglomerate on the northern side. Through the central part

of the ore itself there is considerable pyrites, and on the southern surface of the ore-streak can be seen some original jaspilitic silica, where the hematite is hard. There is in this ore-belt, besides, a considerable amount of limonite, some of it in botryoidal surfaces on quartz crystals, and on hematite (1564). The limonite sometimes is further covered with a thin blue coat, and in some cases, especially in the vicinity of pyrite, there is a surface of coxcomb crystals, like hematite, covered with black, which last possibly is manganese.

A little to the south of this opening is a shaft for hoisting from this pit. It seems to have encountered flinty, gray to dark gray, jaspilyte (1565) judging from a large number of fresh, large pieces that lie near in the dump, (=866 B). Compare 1277.

The principal Breitung opening is very irregular, the direction of strike of the main ore mass winding about in the green schist from east to west so as to run nearly north and south, and abruptly ceasing, or beginning where not expected. Three things are noticeable in conjunction with the ore.

1st. It is heavily jointed, about horizontally, but this jointed part is better ore, and lies below a less jointed mass of jaspilyte, the line between them being characterized by a rotted belt (1566), running diagonally across the face of the wall and descending toward the west. This belt where most rotted is a breccia, so that it is easily dug out even by the hand, and the part that disappears by rotting consists of angular jaspilyte masses. Several other beds of similar soft and rotted material are seen in the ore, sloping toward the west, some of them being lenticular. The occasion of this rotting is the existence of the joint, into which water enters at the top of the ridge where it comes to the surface. The joint cuts everything, rigidly, whether breccia or not, and the breccia is most disintegrated by the moisture and frost. This is evident because, while the rotted belt in the main follows the sloping joint, the rotted belt widens out when it approaches and cuts a breccia layer or mass, in the main rock, and in other places the beds of jaspilyte are preserved entire or mainly so (when not breccia) across the rotted layer.

2nd. The surface of the ore abuts immediately on the greenstone, and the two surfaces are mutually slickensided, the greenstone, in one instance at least, having a fine, curved, semi-basaltic structure which at the junction is nearly perpendicular to the surface of contact. But in other cases the schist is red and hard along the contact for some distance, say for twelve or sixteen inches, and is closely cross jointed and broken, rendering it fissile in small angular lumps.

3rd. In the remaining ridge, which separate the Breitung from the Tower, the firm jaspilyte of which it consists is seen to contain, in several places, and in one place in a somewhat continuous layer traceable, with some interruptions, twenty or more feet, a breccia and conglomerate, one inch to four inches wide, in which are small rounded, or sub-rounded, at least water worn, pebbles of vitreous quartz (1567). There are, on both sides of this band, and in many places over this immediate vicinity, spots of breccia of chalcedonic silica, cemented by smaller breccia and pebbles, as well as by massive chalcedonic silica, all of which consist of the well known chalcedonic silica. But in the above vitreous silica there is no such fine grain as that which characterizes the jaspilitic silica. On the hypothesis of decay and disintegration, as the cause of the granular condition, why is not this condition seen also in these rounded vitreous grains which must be older than the chalcedonic silica in which they are embraced? This observation, like that already detailed on the pebbles of a large boulder seen not far from the Lee mine, negatives all resort to such hypothesis. In this pebbly jaspilyte the vitreous quartz grains, although obvious, are distributed rather sparsely, and the whole space they occupy, forming an irregular and interrupted vanishing belt, or layer, near the center of the main mass, is not more than three or four inches wide, and is not a noticeable band.

North of the Tower mine (No. 8), on the north slope of the north ridge, is a conspicuous shoulder-like protrusion of hard ribbon-jasper, with characteristic undulating and contorted bands. This jasper has five or six thin layers of green schist, or siliceous green schist, running through it, which were cotemporary with the formation of the jasper, since they are flexed with the red and white bands. These layers enter on the eastern border of the exposure and continue zigzag across it, but some of them pinch out or fade out before they reach the eastern border. One of them, after such disappearance, rises again faintly a few inches further west between the same colored bands that enclosed it further east. Figure 7 was sketched from this jaspilyte surface, with the design to indicate the forms and alternations that are exhibited, but no drawing can show all the contortions, and transitions, and alternations. The shaded part is one of the green schist bands. On close inspection it is found to be considerably modified from the typical green schist of the country, having a liberal percentage of silica—indeed it is so siliceous that were it not for the contrast it presents with the smooth, hard jasper it would hardly

Fig. No. 7.—Green schist interbedded and contorted with the jasper ribbons.

be called green schist. Other belts of it, however, are less firm, and fade gradually into a softer (yet comparatively siliceous) light-green schist which cannot be mistaken for anything else than a part of the same rock as the green schist of the country. In case of all these green schist belts, though more siliceous than the average green schist of the country, they have disintegrated and been removed by the action of frost and vegetation, so that along their course across the jaspilyte knob, are little tortuous grooves due to their more rapid decay. A photograph was made of this jaspilyte surface, for which see bulletin No. 6.

In Fig. 7 the hooked expansion and sudden termination of the green schist band are in connection with, and a part of a general contortion in the jaspilyte which bends in the same direction, *i. e.* some of the thin layers do. The lamina of green schist, in an attenuated condition runs from the end of the hook some further and squeezes out gradually, and is lost, the jaspilyte walls coming together, so far as the appearance shows on the glaciated surface. Beyond the keel of the hook, however, in the general course of direction of the band, the green schist band appears again, and continues as far as the uncovered condition of the surface will allow of its

being traced. Here the contortion is in the form of a swelling and lifting toward the north. The beds next south run along without showing any sympathy with this irregularity. There is also a similar protrusion and contortion seen on the north side near the center of the sketch. On the south side here also the jasper ribbons are not disturbed. These contorted protrusions toward the north must have formed before the formation of the succeeding jasper bands in that direction, because, not only do they not participate in the contortion, but easily pass by the protrusions with gentle swells and flexures that are independent of the close crumpling.

The shaded part (Fig. 7) is a belt of green schist. No. 1. at the left is a thin scale of brown jasper. Toward the right further it is gradually replaced by a thin scale, and further still to the right by a narrow ribbon, of hematite. In this brown jasper are lenticules of crimson jasper, presenting a maculated handsome surface. It also shows the fine lamination one thirty-second part of an inch wide which has before been mentioned as a characteristic of the jaspilyte ribbons. It also embraces thin sheets of hematite, and it is cut and cemented by transverse veins of crystalline vitreous silica. No. 2 is mainly hematite, but it has threads (really sections of sheets) of brown jasper; and at the central swell it is rendered impure, being broken, spread, separated by brown jasper sheets, and occupies, with the jasper associated with it, the whole of the swell. No. 3 is a broad band of brown jasper, that also shows the crimson jasper already mentioned. No. 4 embraces a group of hematite sheets interleaved with jasper, too thin and too close to be separately traced. No. 5 is a band of hematite which, at the east end of the sketch is seen to be flexed southward so as to embrace and to coincide with the pot-hook direction of the green schist, but toward the west runs independently of the sharp north-side hook at the west end of the sketch.

The inevitable inferences from a study of this rock surface are: (1) that the two substances, the green schist and the siliceous jaspilyte and the hematite were the product of practically identical forces acting on different objects; (2) that after the formation of some of the narrow bands they were disrupted and contorted before the formation of the next succeeding bands; (3) that the southern side was the lower, and hence the older side, and that the growth was from the south to the north (as the beds now stand); and (4) that there was usually a complete cessation of the deposit of the siliceous jaspilyte when the materials of the green schist were accumulating, and *vice versa*, but that occasionally, as

illustrated in these rather hard bands of green schist, the two substances were deposited simultaneously.

Any theory that will satisfactorily account for the origin of the Keewatin iron ores, must allow for these inferences from the physical structure at the same time that it plausibly accounts for the origination of the elements of which the jaspilyte and the green schist consist.

The fact that there was some force concerned that could fracture the last-laid-down layer without disturbing the deeper ones, and that it was remittent, so that succeeding layers were normally formed and were not fractured is demonstrated also by a sketch made here showing an interrupted layer of brown jasper, the separated parts being surrounded by hematite and embraced in a continuous schist of it, one of the integral bands of the jaspilyte, but themselves also seamed by crystalline silica at other points. See bulletin No. 6.

I am impressed with the indications that this silica is arranged by sedimentation. What was its origin?—probably chemically precipitated; perhaps also that of the St. Peter sandstone, although they are very different in respect to size of grain and in age. The eruptions of basic rock that characterized the Keewatin must have made such changes in the chemical conditions of the oceanic water that silica and hematite were thrown down. Can that be shown? Then came, if not the minute crumpling, at least the general tilting which has brought the beds to verticality.

It is well known that the first attempt to extract ore from these hills was made by George R. Stuntz and John Mallmann. Mr. Mallmann happened to be at Tower at the time this examination was being made, and he kindly pointed out the spot where this working was done, and we made a photograph of the same. It is near the Lee mine, on the south side of the "south ridge," not far west of the east opening (No. 11). By the blast one large lenticular mass weighing three or four tons was rent from the south side of the jasper bluff. The photo is intended to show this. In the hole excavated by the men and by the blast bushes have now grown up, but the course of the drill is still visible on the upper side of the dislodged mass. The photograph is reproduced in Bulletin No. 6.

In the highest of the tunnels of the Tower mine, which discharges southward, and also the most westerly, and at the southern end, is a north and south rock-cut which seems to trans-sect

at a more western point, the rock to which I have so often referred at the railroad cutting immediately south of the Stone mine, about half a mile further east. The mixed and generally interleaved condition of the green schist and the jaspilyte is the same, but at this place, as the cut is across the structure more can be seen of the relations of the two rocks, viz.:

1. The jaspilyte is contained in the schist in lenticular masses, and in thin interleaved vanishing sheets that have their sharp edges upward and downward. This is most manifest, in innumerable instances here within the horizontal space of thirty feet.

2. The jaspilyte is contained in similar masses that terminate east and west in the schist.

3. In the space of 22 feet, north and south on the face of this cut, I count 36 jaspilyte layers, varying in thickness from ¼ inch to 24 inches, all of them having at least 6 inches extent up and down, the rest of the rock being green schist, or jaspilitic red schist (or "shale" similar to rock 1547). Besides these there are some indefinite graywacken layers containing rounded pieces of jaspilyte as pebbles.

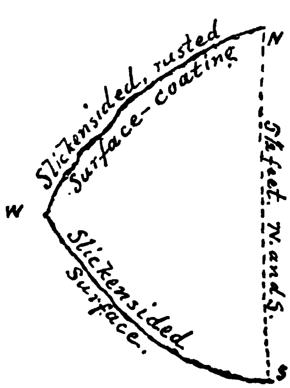


Fig. 8.
Western termination of a jaspilyte lenticule.

4. On the east side of the cut is seen the manner of termination of one of the larger lenticules of jaspilyte, in the midst of the schist, the exposed terminal end appearing unbroken near the track, though broken off at the top by the work of making the cutting. The shape of this western termination is represented by figure 8, which shows a section across the lenticule north and south.

5. Within two inches of this large mass, sketched above, was a smaller, apparently concretionary mass of jaspilyte, about 18 inches in its greater (perpendicular) diameter, appearing on the face of the cut to be entirely surrounded by the green schist and separate from the larger lenticule. Desiring to know whether it was connected with the foregoing large mass, I had a crow-bar brought, and, on making some excavation about it, the smaller egg-shaped lenticule was dislodged entire and fell to the ground. It left a continuous concave socket, the exact imprint of itself, and was coated and smoothed over its whole exterior in the same manner as the larger one, and was wholly independent and

separate from it. It is numbered 1568. It is sharper, in cross section, at the upper end than at the lower, and while about 18 inches in perpendicular diameter it is four and one-half inches thick (n. and s.) and eight inches wide (*i. e.*, east and west). Several small parts, broken from the upper end before it was dislodged, are also given this number. This shows that the egg consists essentially of hard chalcedonic silica, with a little hematite.

6. Within the tunnel, toward the north further, the green schist contains graywacken bands. In these are small pebbles of chalcedonic silica, but, in 1569, can be seen three ($\frac{1}{4}$ in. thick) veins of chalcedonic silica crossing the structure of the green rock at oblique and varying angles. This was taken from the roof of the tunnel, about 15 feet from the southern entrance.

7. In No. 1568 the principal color-bands run across the face of the section, and are not wholly concentric. There is a series of accretionary bands, surrounding these and inclosing them with an outer rusty coating, which gives color to the supposition that the egg is wholly concretionary. These outside bands fade off into the green schist structurally and mineralogically.

8. The mass itself appears to have been a fragment dislodged from its native place, and, while perhaps not yet firmly rigid, to have been imbedded in the materials that now constitute the schist, and with them to have suffered the pressure and upheaval that have brought the beds into their present vertical position. If it had become rigid before it was placed in the schist, it might still, perhaps, have been compelled to take its ovate form by reason of pressure and the mechanical movements to which the beds have been subjected. Judging, however, from the general ovate form of all the jaspilitic lenticules, even the largest, it seems more reasonable to ascribe this shape to some forces or circumstances that attended its origination than to mechanical causes that operated afterward.

Revisiting the old pit of the Stone mine, and noting the so-called jaspilyte *dike*, illustrated in the 15th report (see p. 235), we observed another egg or jaspilyte similar to that just described, though this is partly disintegrated now so as to reveal an original brecciated structure, at least on one side. The harder part is perpendicularly banded jaspilyte. On its exterior is a layer of red shale about one and one-half inches in thickness. This egg is entirely isolated within the schist as shown by the following sketch, fig. 9, made on the spot.

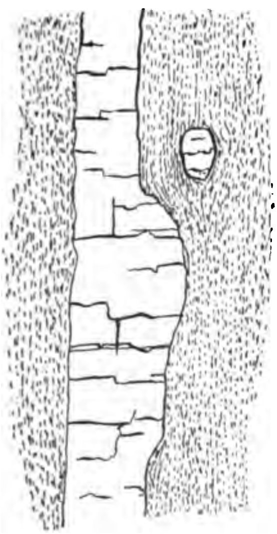
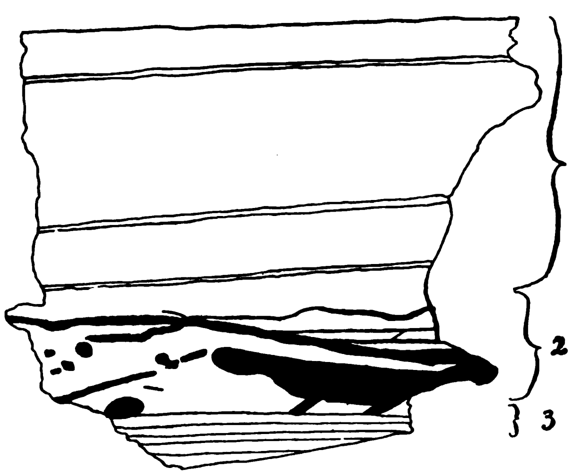


Fig. 9. Ovate lenticule of jaspilyte at the Stone mine, adjoining the "kike" of hematite.

A very interesting and instructive observation was made at the Stuntz mine, or No. 1. In some of the large angular pieces thrown out upon the dump is seen a singular sort of conglomerate and breccia. It is illustrated by the following sketch, likewise made on the spot, fig. 10.

In No. 1, by far the predominating ingredient is white, chalcedonic silica. The same is true of No. 3. No. 2 seems to have been suddenly introduced in the midst of a silica-forming epoch, and as suddenly to have ceased. This interruption caused the coarse fragmental transport of masses from some previously formed green schist and from the previously formed brown jaspilyte. The green schist pieces are somewhat rounded, as would be expected from their softer nature, but the brown jaspilyte pieces are angular.



Explanation of figure 10.

1. White chalcedonic silica, banded with a little pure hematite.
2. Conglomerate and breccia of green schist and brown jasper. The black parts show the shapes of the green schist pieces.
3. White silica and hematite.

This indicates some rupturing agent that acted on both rocks. Indeed, there are many evidences that a frequently recurring force, whatever it was, interrupted the quiet accumulation sometimes of the jaspilyte and sometimes of the schist, and tore up sometimes only the last laid-down thin layer, and sometimes larger thicknesses of the formed beds, and removed them to smaller or greater distances from their native places. This force acted in a common manner on both the acid jaspilyte and the basic schist.

There is hence much reason to suppose that all three of the known agencies for rock-forming were intermittently at work and concerned in the formation of the iron ore, viz.: *Eruption*, to afford the basic eruptive material; *sedimentation*, to arrange it (in the main), and *chemical precipitation* in the same water, to give the pure hematite and the chalcedonic silica. What was the cause of the chemical change in the waters of the Keewatin ocean that brought about the precipitation of silica and hematite, is matter for further research. An ocean, universal as the Keewatin formation, charged with silica in solution, a hot alkaline ocean, on the outburst of volcanoes, might, perhaps, be so far heated, and evaporated, as to be compelled to deposit silica as a chemical precipitate. On the other hand the introduction of cooler currents into the heated region would disturb the equilibrium of saturated solutions, and hematite (or limonite) might be the resultant precipitate. There is reason to believe the earthy, or semi-crystalline, schists of the age of the Keewatin are world-wide, and that, therefore, the ocean everywhere had, in general then, as now, nearly a constant character, only as modified by local or wide-spread volcanic agents.

By the railroad, just south of the Tower pits (Nos. 8 and 9), is a light greenish, novaculitic rock which dips N. 75 to 80 degrees (1557), It passes into graywacke. It is also highly siliceous with both chalcedonic and vitreous quartz, and has a fine white ingredient that gives it a feebly talcose feel, the last being the same element that we have called sericitic. The soft, light green (or white) mineral varies in amount from layer to layer, so that some of the sheets are smooth and soft throughout, and schistose, others being more like graywacke, and others almost a quartzyte in which the vitreous quartz grains can easily be distinguished from the chalcedonic, by their dark color, that is, by their absorption of light which falls upon their fractured surfaces.

I met Mr. W. G. La Rue, of Barraboo, Wis., and he gave me further evidence that there are really two quartzytes concerned, as

already represented by me,* in the geology of the Gogebic iron region. One is that which is the foot-wall of the Colby and Aurora mines, and the other is that which Mr. La Rue describes, viz.: North from the Colby mine, near the bluffs of the gabbro range, which there are plainly visible rising as a series of hills within a mile or less of the village (Bessemer), he was employed to explore for ore by shafting for some parties who thought there was ore near the gabbro. He said that under the gabbro he found a quartzyte, and a sandstone, the two differing only in induration, one being more easily excavated than the other, both consisting of crystalline quartz. He shafted under the quartzyte in a conglomerate of iron ore, which seems to be comparable to that found in a similar situation at Ishpeming, Mich.,** and at Cascade near Negaunee, and after a time he found that the conglomerate turned almost at a right angle toward the north. He did not seem to know what was under the conglomerate, but he told me he found the quartzyte and sandstone together 235 feet thick. This was in the sw¼, ne¼ sec. 10, 47-46, Michigan. This is apparently the unconformable conglomerate and quartzyte that I noted at Bessemer, at the railroad, in a small exposure, in my sixteenth report.

IV.

The Age of the Gabbro.

In attempting to correlate these observations with those which have been made and recorded in previous years, there is some difficulty in fixing the stratigraphic place of the gabbro eruption. It was inferred by the Wisconsin geologists that the gabbro sheet was the bottom layer of the great Cupriferous formation, or Keweenawan, and this was accepted and has been followed unquestioningly by the writer in all previous reports and discussions of the crystalline rocks of the state. The age of the great Cupriferous formation, with its traps and conglomerates, in part at least, has been established, with increasing evidence and positiveness as on the horizon of the typical New York Potsdam—at least at the horizon of a quartzyte which overlies the Animike of the northwest.

Thus the gabbro sheet was carried to the same age. When the gabbro was found to be interbedded with a quartzyte in northeastern Minnesota, and to lie upon and overwhelm it, (the Pewabic quartzyte), it was a necessary inference that that quartzyte was the

* See 16th Annual Report. pp. 55-6.

** See the 16th Annual Report, pp. 44-47.

equivalent of the Potsdam—or at least of the bottom quartzyte of the Cupriferous—and hence must lie over the Animike, although at no place could the Animike be seen interposed between it and the gneisses of the Giant's range. When it was found that this quartzyte which is the principal iron horizon of the Mesabi range, shows evidence, in the region eastward from Pokegama falls, of passing below the body of the Animike strata, necessarily carrying with it the gabbro sheet, the idea that the gabbro has possibly been put into a wrong position is brought out prominently before the student of northwestern stratigraphy, and he is disposed to call in question the datum from which some important conclusions have been drawn.

The gabbro sheet itself is a wonderful formation, both in geographic extent, and in vertical thickness. It is also wonderful in the diversity of lithological variations that it displays—*i e*, when it approaches the characters of a normal doleryte, or when it is interstratified with beds of sedimentary origin, or when it is modified by contact with them. Yet its persistence under erosive and atmospheric agents, and its great volume, causes it to appear prominently and suddenly, and frequently, giving it the reputation of greater area and importance than it deserves. This is rendered more marked by the fact that its line of outcrop is characterized by heavy drift deposits which have covered up the less persistent formations and hid from inspection their true relations both to the overlying and underlying strata. It was hence a very natural conclusion that its advent was the opening scene of that succession of eruption and sedimentation which is displayed in the Cupriferous formation and that the whole should be grouped together under that single designation.

It is the design of this chapter to call attention to some facts that indicate that the gabbro lies below the Animike, (Huronian black slate), in great part, and that the later trap eruptions, continuing through the Animike and the Potsdam, (*i. e.*, the Huronian quartzyte), probably constitute the age and the strata of the Cupriferous formation—the "Keweenawan" of the Wisconsin geologists In other words it seems as if the Keweenawan series, in its full scope, embraces not only the age of the Huronian, (Potsdam), quartzyte, but also of the black slates of the Huronian that underlie the quartzyte.

1. The most important and significant fact that bears on the stratigraphic position of the gabbro, respecting its relation to the Animike black slates, is its occurrence along a wide extent, reaching from Gunflint lake southwestward as far as to the railroad

crossing at Mallmann's, (at least), *next to and immediately south* either of the gneiss of the Giant's range or of the "greenstones" of the Kawishiwin, without the appearance of any of the black slates between them. There is an appearance of *quartzyte*, with olivine grains and with magnetite, geographically between the gneiss and the gabbro, the same being unquestionably the Pewabic quartzyte seen near Gunflint lake. This quartzyte sometimes is impure and limonitic, and seems to be the chief iron horizon of the Mesabi range. This near conjunction (which is sometimes apparently an exact contact) of the gabbro with the gneiss, and the absence of the Animike proper between them, has been supposed to be due to a local overlap of the gabbro beyond the strike of the Animike, covering it from sight, the idea being that the gabbro flowed back northward over older formations, and came on to the gneiss.

2. Although there has not yet been any careful microscopic examination into the differences between the typical gabbro (for instance that seen at Rice's point, near Duluth) and the eruptive rocks that overlie the Animike black slates at Gunflint lake and eastward to Pigeon point, it has been noted that there are macroscopic distinctions which ought to be explained in case of a supposed parallelism of one rock with the other. The supposition has been that they are stratigraphically and chronologically the same, and that the differences were only local and unimportant. It was this assumed parallelism and the evidently later age of the eastern outcrops (the "crowning overflow" of the Animike) which has led to the placing of the gabbro later than the Animike. There is absolutely no other evidence. If these two eruptive rocks are not contemporary there is not only no reason against but considerable evidence in favor of placing the typical gabbro (such as at Rice's point, and at Little Saganaga lake) below the body of the black slates.

3. Boulders of characteristic gabbro and of red syenite, and of quartz porphyry, occur abundantly in the later "traps" of the Cupriferous. The quartz-porphyry pebbles are so abundant as to constitute the well known thick beds of coarse conglomerate; and quartz-porphyry layers or lenticular *sheets* are interbedded between the trap sheets. This quartz-porphyry in some cases appears to have originated in its present condition of interleaved sheets during the time of the Cupriferous. This is observable at the mouth of Baptism river, and at the Great Palisades. At these points, however, owing to the proximity of bosses of gabbro rising above the rest of the country about, it is certain that those portions of the Cupriferous which contain the original quartz-porphyry beds, are near

the bottom of the formation. This is further shown by the existence, in the same region (at and near Beaver Bay), of large boulder-masses of gabbro in the trap flows, evidently derived from the neighboring gabbro hills. From this point, northward to the gneiss of the Giant's range, nothing is visible, in the form of rock *in situ*, except gabbro, or some "muscovado"-like rock described at some outcrops somewhat further west* by H. V. Winchell. The region is not fully explored, but it appears from all that is known, that there is nothing to be found of the typical, thin black slates of the Animike. It is as reasonable to infer that they followed after the gabbro flood, as that they preceded it. In case they followed after it, their typical characters were destroyed in this region by the frequent outbursts of igneous eruption, and they blended with the tuffs and shales and basic sheets that constitute, on the north shore of lake Superior, the lower portion of the Cupriferous formation. In case they preceded they must exist buried below the gabbro, as hitherto supposed.

4. In further consideration of the possible infra-position of the gabbro mass, below the Animike proper, attention should be given to the record of the deep well at Duluth, as given in Bulletin No. 5, of the survey. The interpretation of the record, given on page 34, shows, below the gabbro, (which is found to be 220 feet thick), quartzyte and conglomerate beds interstratified with imperfectly characterized gabbro, the whole having a thickness of 67 feet. Then followed trap sheets, and fragmental tuffs, for a thickness of 89 feet. Then follows what was thought to be the Animike, "evidently the Thompson slate formation." In the light of the foregoing (Nos. 1, 2 and 3) however, and on reviewing the descriptions given of the drillings of this well (pp. 31-34), the writer considers it quite doubtful whether "the Thompson slate formation" is on the horizon of the Animike of the northwestern part of the state. The existence of a minutely granular condition in the quartz (Nos. 39, 46, 50), recalling the "chalcedonic silica" of the Keewatin, and of a distinct slaty cleavage not due to sedimentary bedding (Nos. 28, 36, 37, 53), and of hydromicaceous or sericitic schist (Nos. 28, 30-39), and kaolinic itacolumyte (No. 41) noticed and recorded when the writer was impressed with the expectation of finding Animike characters, must be admitted to point to the Keewatin schists and graywackes. There are other coincident descriptions of the outcrops about Thompson, to be found in the tenth annual report (pp. 12-31) which throw doubt on the supposed parallelism

*Seventeenth report, p. 90-91, Samples 387 (H).

of the Thompson slates with the Animike of northwestern Minnesota, viz:

1. Folia of quartz and slates, or schists interbedded, (p. 12, No. 454, p. 16, No. 466, p. 17, No. 472), is a character not known in the Animike.

2. There is a conspicuous perpendicular slaty cleavage in all parts which is not dependent on the sedimentary structure, a character not seen at all, or rarely, in the Animike in the northwestern part of the state.

3. The clay slates are frequently pyritiferous, (p. 18, No. 473.)

4. Feldspathic graywacke (often called gray quartzyte in the original descriptions) is a conspicuous feature in the strata north from N. P. Junction (p. 28, No. 504).

It is only intended here to make record of these reasons for hesitating before accepting the parallelism of the whole of the Thompson slates with the Animike of the northwestern part of the state, notwithstanding the fact that it has been accepted hitherto, both by the Wisconsin survey, the U. S. geological survey, and by the Minnesota survey.

5. On the supposition that the Animike black slates are involved in the Keweenawan, and, while overlying the gabbro, lose their typical characters at points further southwest, the interbedding of the Animike with beds of trap-rock, which is a common feature about Gunflint lake and on the shores of Loon lake, is easily explained, and indeed falls into place as one of the to-be-expected facts of such a period of recurring eruptions. It also obviates the necessity of a supposed change in the character of the eruptive rock, *i. e.* that the gabbro of Rice's point and Little Saganaga lake becomes, on Pigeon river, the dark or greenish trap-rock and the dioryte which inter-bed and characteristically overlie the Animike, forming the well-known "crowning overflow" of that region.

V.

Further Observations on the Typical Huronian, and on the Rocks about Sudbury, Ontario.

In the summer of 1889, on the occasion of the Toronto meeting of the Geological Society of America, the opportunity was improved, both in going and in coming, to extend a former acquaintance made with the rocks of the region north and east of lake Huron.* A resume of these observations was read before

* Compare the sixteenth annual report of the Minnesota survey.

the Minnesota Academy of Natural Sciences at the October meeting, 1889. In order that the bearing of the following facts and interpretations may be understood by any who have not given close attention to the developments of Archean geology in the northwest during the last few years, a brief resume may be the best introduction.

It is well known that in the term Archean are included two groups of rocks, the Huronian and the Laurentian.* These terms are of long standing, and have been used in the geological literature of nearly all parts of the world, wherever geological research has been carried on in the oldest rocks. They were proposed by the Canadian geologists in 1855, and were in a few years adopted by the geologists of the United States, and they are yet found in nearly all of the text books of geology in use in this country, with the signification that the Canadian geologists have given them. It is not necessary to say here what inconsistencies were involved in this course of accepted nomenclature, nor what injustice was rendered to American geology by American geologists, nor what were the motives that apparently actuated the leaders of American geological opinion thirty or forty years ago. It is only necessary to say that *Huronian* was in conflict with *Taconic*, and that *Archean* was in conflict with *Azoic* as well as *Atlantic*, names that had been proposed earlier by United States geologists.

With the revival of work on the older rocks in the northwest, about ten years ago, it was found that the original Huronian of Logan and Murray had been amplified, by the reports of the later assistants on the Canadian survey, by an important extension of the names downward, over many varieties of rocks not mentioned in the Huronian region by those who first described the Huronian formation, and even over all the stratified, or schistose formations, down to the massive gneisses and syenites which are called distinctly *Laurentian*. This extension had also been accepted by many, if not by all, geologists of the United States. This was true of the late surveys of Michigan and Wisconsin, and of the earlier reports of the Minnesota survey, and was maintained, but haltingly toward the last, by Prof. R. D. Irving up to the time of his death.

In order to get a correct understanding of the character of the Huronian rocks of the original Huronian area, several recent reexaminations have been made of the area described and mapped

* C. H. Hitchcock has called attention to the fact that G. W. Featherstonhaugh proposed the term *Atlantic* for these rocks many years before Prof. Dana introduced the term *Archean*, and before Foster and Whitney employed the term Azoic. See *American Geologist*, vol. V, p. 199. Also compare *Geology of New Hampshire*, vol. 1, p. 525.

by the Canadian geological survey. The first was that of Prof R. D. Irving, who came to the conclusion that the so-called Animike formation of Minnesota and Thunder bay (in Canada) is the equivalent of the original Huronian. But, unfortunately for the cause of correct nomenclature, Prof. Irving, who had embraced the expanded Huronian in his Wisconsin work, so continued his trip beyond the limits of the original Huronian, that he found, eastward from Algoma, a series of rocks which he thought also belonged in the same series with those at Thessalon, and so verified (?) his classification published in the Wisconsin report. Hence, while correctly assigning the real Huronian to its western equivalent (the Animike slates and quartzytes), he failed to see that outside of the mapped Huronian of Logan and Murray the name had no right to be extended over a different formation, for eastward from the mapped area another formation at once begins and hence, also, he continued to maintain that the Animike could be extended downward so as to cover all the lower schists and graywackes and iron ores of the Northwest.

Prior to this an unconformity and a profound change in lithology had been discovered between the Animike formation and the schists below it, in the vicinity of Gunflint lake; and, at a later date, those schists had been examined in the region of the Lake of the Woods, and while placed doubtingly in the Huronian by G. M. Dawson, and by Bell, had by Mr. A. C. Lawson been given a new name, (Keewatin) who exempted them, questioningly, from the Huronian system, showing that they pass unconformably below the Animike which had been said by Prof. Irving to be the real equivalent of the Huronian on the north side of lake Superior.

In the sixteenth report of the Minnesota survey will be found two other recent descriptions of the original Huronian rocks, from an examination made in the summer of 1887. Here the Huronian formation is distinctly limited to the strata described at first and named Huronian by Logan and Murray, and the name given by Dr. Lawson for the underlying schists (Keewatin) is adopted unqualifiedly, and extended over those schists in Minnesota. The same classification had been adopted also in the fifteenth report of this survey, but without the authentication that comes from a fresh examination of the old data.*

As the current idea of the Huronian, as at length extended by the Canadian geologists, began to be questioned, several re-affirma-

*The writer has reviewed the history of the Huronian system as expounded by the Canadian geologists, in the AMERICAN GEOLOGIST. *Methods of stratigraphy in studying the Huronian.* Vol iv. p. 342.

tions of its correctness have been published by Drs. Selwyn and Bell. It was in the light of these discordances that some recent re-examinations have been made, and the following notes were recorded when on a joint excursion with several geologists from the Toronto meetings of the American Association for the Advancement of Science, and of the Geological Society of America.

North Bay.—The rocks about North Bay,* on the northeasterly shore of lake Nipissing, placed in the Laurentian by the Canadian geologists, consist of dark-colored, micaceo-hornblendic gneiss, or gneissic schist. They are distinctly bedded by sedimentation, the characteristic belts of which run parallel for long distances. They are generally fine-grained and often red-weathering, recalling by this, as well by their structure and mineral composition, some gneisses seen and described by the writer in 1886,** on the Kawishiwi river. These are massive, fine-grained, red, very siliceous beds, as if from a quartzyte, but the most of the rock is closely laminated varying from very micaceous to very orthoclastic. The strata stand about vertical, but generally show some inclination southward—but sometimes northerly. The strike is about NW. and SE. Some of the gray gneiss (1573) which weathers reddish (1574) becomes contorted in some places and infolds, unconformably, masses of a dark rock very different from the gneiss (1575). These masses are wrapped round continuously with unbroken, but curved laminations of gneiss, the laminæ, at some distance from the enclosed masses, becoming straight again, and running in their usual course. These contrasted foreign enclosures have a different aspect, and a different composition from the micaceous belts of the gneiss. They are both micaceous and hornblendic, but mainly hornblendic; non-laminated and generally containing multitudes of fine crystals of cinnamon-garnet. In some places these masses are very large, and cannot be seen to be enclosed, but cut off the gneiss and replace it in large areas. The geology in general here recalls that of Northeast cape in Bassimenan lake (fifteenth report, p. 358), as well as that mentioned on the Kawishiwi river. The rock has been plastic *in situ* and molded about masses of foreign intruded rock, apparently a basic eruption, but has not been molten and extruded. In general the horizon to which it would be assigned in the Minnesota scale, would be near the bottom of the crystalline schists (the Vermilion series), or very near the Laurentian gneiss. It is very probable

*The rocks about lake Nipissing have been described in the Canadian reports by Alexander Murray, for the year 1854, for the year 1856, and maps of the atlas accompanying the volume.

**See the fifteenth report, Minnesota survey, p. 353.

indeed that rocks like these have been included in the Laurentian in some of the descriptions and map-coloring in our reports. Since it graduates, in Minnesota, conformably on the one side into typical gneiss containing very much less mica, which would be placed unhesitatingly in the Laurentian, and, also, on the other hand, fades out by the loss of the black mica, and by the acquirement of a sub-crystalline and finally a fragmental texture, into the typical rock of the Keewatin, it is evidently only an arbitrary line of separation that can be drawn distinguishing it definitely from one or the other. The principal difference between it and the Keewatin consists in its more nearly perfect crystalline structure. The principal difference between it and the greater portion of the Laurentian gneiss in Minnesota consists in its greater percentage of black mica. The prevalence of the black intrusive masses oc-

Fig. 11
Included hornblendic mass at North Bay, causing contortions in the gneiss.

Rock Samples obtained at North Bay are numbered as follows: 1573. Gray gneiss, the general rock at North Bay, after the weathered surface is removed. 1574, Reddish weathered gneiss, a surface condition. 1575, Hornblendo-micaceous and garnetiferous dark rock embraced in the gneiss (see figure 11) as foreign masses, and as large areas, the laminations of the gneiss being wrapped about them entirely and roughly conforming to their exteriors.

curring transverse to the strike of the gneiss, and in a manner involved with the gneiss, showing a mutually plastic condition of the two, is a characteristic of the Vermilion series about where the transition to the Laurentian occurs with an *eruptive unconformity*, the foreign intrusive rock being the dark, hornblendic masses and not the gneiss. The manner of occurrence of one of the smaller hornblendic and garnetiferous dark masses was sketched on the spot and the same is represented on page 51 (Fig 11). This was near the public school house at North Bay.

Wahnapitae. A sample of that which is here called Huronian by Dr. Selwyn is numbered 1576. At this point the formation changes from the Laurentian to the next higher, or supposed younger, formation. The train stopped but for a moment, but with difficulty a small sample of the country rock was procured. On examination it was found to be of a hydro-micaceous schist, silky-sericitic, evidently a part of the Keewatin. Subsequently Dr. A. C. Lawson re-examined this point, in order to get a better idea of the relations of the formations, and according to verbal description from him, there appears to be an unconformity of stratigraphy at Wahnapitae. similar to that at Penokee gap, Wisconsin; at the immediate contact the lower rock is the fine, micaceous gneiss, or mica schist, probably belonging to the series seen at North Bay, and the upper rock is quartzyte and gray argillyte interbedded.

At the Stobie copper and nickel mines, about three and a half miles north from Sudbury, there is a large exposure of greenstone, coarsely fibro-crystalline with hornblende (1579), seen south of the mines rising in high ridges and domes, resembling the ridges of the Kawishiwin greenstone of Minnesota (see the 17th annual report), though much more coarsely crystalline. This lies below the rock that contains the copper and nickel ores, and was fruitlessly penetrated by a costly shaft in pursuit of the ore-bearing rock several hundred feet. The present mining is done in a quartzyte (?) or at least a quartzose, apparently fragmental rock, which is superficially buried under a thick deposit of rusted debris, or gossan-cap, the result of its own decay. The ore permeates this gray granular rock in the form of sulphides which in this superficial layer is converted to oxides and carbonates. The mines are still not deep, although some tunneling has been done in the hillside. Outwardly the resemblance of the lithology of the lower rock (1579) to some of those described in northeast Minnesota belonging to the eruptive portions of the Keewatin is so great, that it is reasonable to suggest that it represents the lower formation. But the quarried rock cannot be assigned with any certainty to the

same horizon. Its resemblance to some of the lower feldspathic, gray quartzytes seen in the Animike (Huronian), and its manner of occurrence in a low bluff apparently dipping at a low angle away from the lower greenstone, as well as the similar occurrence of abundant sulphides of iron (and nickel ?) in the lowest parts of the Animike west of Gunflint lake, caused me to regard the ore-bearing rock, on lithological evidence, as belonging to the true Huronian, and hence as unconformable on the other. Samples of the ore are 1578, and of the ore-bearing rock 1577.

At the Copper Cliff mine, three and a half miles s. sw. from Sudbury, according to Dr. Selwyn a dioritic dike (1581 and 1584) runs through the country, and the ore is associated with that. The next rock, on the north, is a red felsyte (1583), and the relations between it and the mined rock were not made out by anything I saw in the short time we were on the spot. The red felsyte becomes protogenic, or granitic, and also has fine black mica-scales developed in it in other places. The ore of this mine is represented by No. 1582. Eastward from the mine is a small knob of red felsyte, and next, about ¼ mile from the mine, is a knob of coarse conglomerate in which there are large boulders of red-weathering felsyte like that at the mine, also of laminated fragments of a grayish rock like a fine-grained graywacke or coarse argillyte, and probably others. The matrix is gray and finely siliceous, of which No. 1585 shows an average.

At 1½ miles from Sudbury, toward Onahping, the train stopped for the examination of a peculiar rock (1586), recalling, but not identical with, the hornblende-porphyry of Kekekabic lake (No. 751), but having much coarser crystals, and a more evidently conglomeritic original structure. At ¼ mile further nw. this conglomerate is more crystalline, the matrix being reddish-weathering felsyte (1588), and the included masses being of a dark basic rock probably originally eruptive. In places this felsyte becomes granitic, and the large dark fragments appear as boulders and included masses more or less modified in shape, embraced as in a once plastic or molten rock. The aspect in such cases is much like some Laurentian, and if it were to be found to extend over a large area with these characters, it would probably be assigned to the Laurentian by any geologist. This illustrates one of the difficult problems involved in the use of the term Laurentian. This rock is in the midst of what passes for *Huronian,* and is derived from a fragmental rock which is like many seen in the "Huronian" of the region. It assumes first a porphyritic aspect, then it is felsitic, weathering reddish with a pronounced orthoclastic ingredient, then,

with a coarser grain, it appears like an eruptive granite embracing masses of foreign basic rock. This is similar to some observations that have been made in Minnesota in the Keewatin, and particularly on the upper waters of the Kawishiwi river. Similar transitions have been observed in Michigan. *

At the Murray mine the ore (1589) is in a conglomerate, disintegrating and limonitic.

At Vermilion lake (*i. e.*, at the crossing of the Vermilion river), is a repetition of the falls, ridges and rapids seen at Thompson, Minnesota, the whole being manifestly of the same age, and supposed to belong to the Animike or true Huronian. The dip of these slates is 45° towards the S. Dr. Bell stated that the train, before arriving at Vermilion river, had passed over these slates for about five miles, viz; through a very flat and good agricultural tract, indicating a profound change in the underlying rock, inasmuch as, up to the place of entering on these slates, the country had been very rough, with frequent exposures of the rock. The slate is black, (or purplish black when dry), generally fine grained, yet with some evident grains of quartz, (No. 1590). In it are some curious calcareous bunches, or "concretions," which recall the soft masses in which Dr. T. Sterry Hunt reported evidences of a "keratose sponge," found near Thompson, Minnesota. Some of these masses are two feet in diameter, with rounded outlines, presenting on the weathered or glaciated natural surface a striking contrast with the rock which encloses them. They are locally designated "snow-shoe tracks." This brownish, calcareous material is represented by No. 1591.

From the Vermilion river, traveling still northwest, we passed on to a lower series of strata, the dip being to the south-southeast. This is a "slate conglomerate," (1592), and causes an immense ridge, 150 feet in hight, more or less. Into this rock Dr. Bell states that the slates at Vermilion river graduate conformably, and indeed so they seemed to do; and in this respect the succession seems to be like that seen in the region of the original Huronian northward from the Thessalon valley, as described in the sixteenth report of the Minnesota survey. This "black slate," therefore, and the underlying "slate conglomerate" should be considered as portions of the Huronian as described by Murray and Logan.

Immediately after passing this ridge of "slate conglomerate," the average surface level subsides again, and the country is more even. But the rock that succeeds to the slate conglomerate toward the northwest, is mainly a reddish felsyte, similar to that seen

* Compare the 15th and 16th Annual reports, Minnesota survey.

in the vicinity of Sudbury, and necessarily underlying the foregoing slate and "slate conglomerate." It is also broken up into irregular small knolls, and presents a confusion of dip and strike that contrasts strongly with the regularity of dip and strike maintained by the overlying formation. This formation seems to have supplied many of the felsitic and granitic boulders seen embraced in the slate conglomerate. There was no opportunity to make search for the immediate contact of the "slate conglomerate" on this rock, but if the observations that have been made recently in the area of the original Huronian, and on the Animike in Minnesota, be taken as guide, there would be found, on making such a search, a distinct overlap unconformity at such contact line.

From this point (Onahping) the excursion car turned back, and although it was planned to make a stop at Wahnepitae bridge to allow those interested to inspect the contact there between the Laurentian and the "overlying" formation, a heavy and continuous rain interfered, and the car returned directly from Sudbury the same evening to Toronto.

After this excursion I had the pleasure and the benefit of a further examination of the original Huronian region in company with Dr. A. R. C. Selwyn and Dr. A. C. Lawson. We walked from Algoma to Serpent river along the Canadian Pacific railway, noting the rock cuts, and the following is the general result of my own notes.

Quartzyte extends from Algoma to about one mile east, when a greenish slate (1593) appears with a dip s. 10° w, 45°—65°. This is fine grained and sometimes cut by dioritic dikes of epidotic rock, like that at Bruce. Next appears at 1½ miles from Algoma, a dark-gray roofing-slate (1594), the cleaving and bedding dipping southerly at an angle of about 75°. Below this is an immense stratum of "slate conglomerate" (1595), (3d of Logan's map of 1863), which is charged with boulders of various kinds of rock, the most conspicuous being of red granite. We then met with a soft fissile argillyte (1596) which hardly has any remaining sedimentary banding, and in it are elongated lenticular sheets of silica, apparently chalcedonic (1597). This resembles some seen in the Keewatin but there could be seen no contact, as the exposure is in the form of an isolated ridge which passes below the drift on all sides, so far as ascertained. It seems to be not a part of the argillyte before mentioned. This stands, in some places, nearly vertical. Then comes on a great quartzyte member (1598), but this is quite different from that seen at Algoma, and in the Thessalon valley. It is uniformly very fine-grained, and is apparently Logan's "gray

quartzite," the lowest included by him in the Huronian. It is at any rate the same as the *Missasaugui quartzyte*, so-called in the 16th Minnesota report, which was there supposed to be Logan's lowest quartzyte. It is gray within and weathers red. The railroad swings back and forth across the ranges of this rock, following the easiest route, and affords some good opportunity to examine it. It exhibits important differences from the upper Thessalon quartzyte. It is interbedded with abrupt transitions from hard, apparently chalcedonic (?) silica, or quartzyte, to fine chloritic schists, the beds of the quartzyte being from a foot to two feet in thickness, and those of schist from two to eight inches. This extends for at least four miles, with some interruptions, the road passing in general at an oblique angle across the strike of the formation. The beds are for long distances straight and parallel. At a distance the face of the rock recalls the regular and straight furrows of a plowed field, the schist weathering and washing out easier than the quartzyte. Such a view is seen on the south side of the track about four miles from Algoma.

At a point still further east the conglomerate recurs by the track. Here it holds quartzyte pieces like the quartzyte just mentioned, and also others of red granite, and numerous pebbles of bluish vitreous quartz. It also embraces pieces of nearly black argillyte (1599) which is soft and has a nearly white streak.

After an interval of nearly a mile and a half of no rock exposure, we encountered a low boss of fine-grained black mica-schist (1600); with siliceous veins running with the strike. Then we found some argillitic beds in which were some crumpled white sheets of apparently chalcedonic silica (1601).

After an outcrop of coarse quartzyte (1602) resembling somewhat the Thessalon quartzytes, but less granular, whose stratigraphic position we could not make out, on account of the interrupted nature of the exposures and the variation in the direction of the track, we noticed two dikes of more recent diabase (1603) cutting the slate conglomerate and running nearly coincident with the strike, and having a columnar structure about horizontal. Under the conglomerate here, *i. e.* just before reaching Cook's Mills, at the mouth of Serpent river, conspicuous outcrops appear of a fine mica schist (1604), which is probably the recurrence in force of the mica-schist before mentioned (1600). It is not bedded but massive, and becomes hornblendic, recalling some parts of the Vermilion series of Minnesota. This continues to Cook's Mills and forms the outcropping rock at the station and about the village. No positive observation was made on the stratigraphic relation of this horn-

blendic mica-schist to the slate conglomerate, but its place is assumed to be below the conglomerate because of the known relation of the Huronian (*i. e.* the described Huronian of Murray and Logan) to such rocks in other places.

SUMMARY OF THESE OBSERVATIONS.

It appears, therefore, that both northwest from Sudbury and eastward from Algoma there are two formations. The slate and the slate conglomerate in both sections constitute the upper formation. In the region northwest from Sudbury the underlying rocks are largely felsitic, but are also micaceous, and at the Stobie mines become hornblendic. These changes are identical with changes that are known to occur in the Keewatin in Minnesota. In the section eastward from Algoma the underlying formation seems to be the Missasaugui quartzyte with interbedding of green fissile schist, in part, and a mica schist varying to hornblendic schist, in part, the latter being further east.

There seems to be some irregularity in the order of succession in the section eastward from Algoma, bringing in several outcrops of strata that belong higher up in the series. If this be not illusory, and due rather to the winding of the railroad from north to south to avoid the hills, it may be accounted for by such faulting and upheaval as have been described in Minnesota, such as have produced the sudden, but indistinct, unconformities and transitions from the Huronian to the Keewatin, that have been described there. Further, the quartzyte which has been alluded to as the Missasaugui quartzyte, and supposed to be Logan's lowest gray quartzyte, is probably not his lowest gray quartzyte, but it is rather a constituent part of the Keewatin. It is allied in all its lithology no less than its persistent verticality to the Keewatin and seems to have been formed in the Keewatin ocean in the same manner as the jaspilyte beds of that horizon, *i. e.*, by chemical precipitation, the green schist layers showing such advent of basic eruptions or volcanic ash as could form chloritic schists in the same way as in northeastern Minnesota. The "lower gray quartzite," (No. 5 a), of the original Huronian, according to Logan's map of 1863, appears a few miles east of Thessalon at the lake shore, and there produces an unconformable contact on the gneiss of the Laurentian. This contact has been examined by Prof. Irving and more lately by Dr. A. C. Lawson, and they concur in the statement that the conglomerate is a pudding-stone of

rounded masses, having a quartzyte matrix. There can be but little doubt that it is the same as that seen in the vicinity of Thessalon, and hence that it is the Thessalon quartzyte and *overlies* the slates and slate conglomerates, being near the top rather than near the bottom of the original Huronian. This mistake is apparently the same as made in eastern New York and in Vermont, where the granular quartz (?) and the Potsdam (or red sandrock) seems to overlap and hide from sight the formation immediately older, and lies in unconformity on a still older terrane—on the east on the gneiss of the Green mountains, and on the west on the gneiss of the Adirondacks. It caused the early geologists to question the existence of any such formation as the Taconic—that great series in which has been brought to light latterly a wonderful fauna of primordial life, and which extends from the Atlantic slopes to the western basis of the Rocky mountains. This overlap unconformity implies a sinking of the pre-existing land, and of the ocean's bed, bringing the later formed strata over the beach-limit that existed before.

We may conclude therefore that the observations that were made on the recent excursions confirm, at least do not contravene, the views lately set forth by Irving, Bonney and Lawson, and the conclusions published by the reports of the Minnesota survey, to the effect that the Huronian system, as now defined and understood by the Canadian geological reports, really embraces two or three formations; that one of these is the true Huronian, as at first described and mapped by Murray, another is the Keewatin of Dr. A. C. Lawson, containing the iron ores at Tower, Minnesota, and another is the series of crystalline schists which we have styled Vermilion series. In other places these three formations have been fully treated.* They are distinctly separated by lithology and unconformities that have been noted from Vermont to Minnesota, and

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[NOTE.—At Algoma are occasional very interesting boulders (1605). They contain large (and small) rounded, whitish-green feldspathic spots which are distributed somewhat like porphyritic crystals. but they have not the angular periphery of crystals. They are in a matrix of ordinary diabase of dark green color, and the spots make the rock noticeable, their largest sizes being somewhat larger than an inch in diameter. Some of these boulders are put in the foundation wall of the great hotel which the Canadian Pacific railroad projected at Algoma, and that is where we saw them first. Mr. Selwyn recalled the dike cutting the Animike on the high ridge back of Silver Islet, as the only spot known where such rock is in place. This dike was visited in 1879 by the writer and his samples are numbered 601 (Tenth annual report, p. 56), but the crystals in the dike are distinctly angular and not noticeably greenish. These boulders are suggestive of the existence of such source in the country toward the north from Algoma.

Another common boulder at Algoma is constituted of quartz-pebble conglomerate, the pebbles in which are of that ambiguous character seen in the Missasaugui quartzyte—whether fragmental or of chemical precipitation. While the boulders themselves are referable to the Thessalon quartzyte, high up in the Huronian, the pebbles that compose so large a portion (1606) are referable to that unconformably underlying vertical quartzyte (the Missasaugui quartzyte) seen, as above described, a few miles east of Algoma.]

* See the Seventeenth Annual Report, Minnesota survey.

should no longer be included under a single term—at least not under the term Huronian, which at first had a correct and adequate definition embracing but one of them.

VI.

Additional Rock Samples Numbered.

[Collected by N. H. Winchell, intended to illustrate his field notes in 1888 and 1889.]

1501. Vein rock and pyrites, from the quartz vein supposed to be auriferous, at Eagle Nest lake, east of Vermilion lake; according to Robert Angst this also contains metallic copper. [See description of this vein in the 15th annual report, p. 32.]

1502. Chemical silica, Tower, embraced in considerable masses in immediate proximity to the chalcedonic, in the green schist.

1503. Chemical (granular?) silica, in a vein about half an inch wide running transverse to the green schist, Tower.

1504. Chalcedonic silica, immediately adjacent to 1503; reddish, in thin laminations.

1505. Some of the schist seen interstratified in argillitic slate at the low "slate" knoll south of the "south ridge" and west of Tower.

1506. Four samples showing the relations of the chemical silica to the hematite, at the Lee mine, near Tower.

1507. Brecciated jaspilyte, cemented by a finer breccia of the same. From a boulder, but fairly illustrating the beds in situ.

1508. Black schist with pyrite balls, at the pits at the N.W. base of Chester peak.

1509. On the top of Chester peak some small veins consist of chalcedonic silica, crossing the jaspilyte banding.

1510. At Ely; a sample of the green schist showing the forms of two boulders, and the darker green rock separating them.

1511. Amygdaloidal portions of some of the boulders, showing the tubes perpendicular to the surface; from the green agglomerate at Ely, at the railroad cut.

1512. Chalcedonic silica from veins and spots in the rock 1510.

1513. Vein matter in 1510, similar to 1501. Probably auriferous.

1514. Sample of the gneiss at the Hinsdale quarry, *i. e.*, in the Giant's range.

1515. Frazer's quarry, North Redwood P. O., near Redwood Falls, on the Minnesota river. Massive, gray, uniform gneiss, without bands of color.

1516. Same place. Gray gneiss, with alternating and inter-shading micaceous and feldspathic belts.

1517. Same place; samples showing much red orthoclase.

1518. Gneiss, with much red orthoclase. Morton quarries, near Redwood Falls.

1519. Gneiss, showing inclusion of a micaceous, "black rock." Morton quarries.

1520. From a granite mound on sec. 12, T. 111—38. Redwood county. A bedded granitic rock, showing no red orthoclase.

1521. The gray quartzyte at Pokegama falls on the Mississippi river near Grand Rapids. Compare 257 (H)—259 (H).

1522. The gneiss at the upper falls of Prairie river.

1523. Showing micaceous schist in alternations with the gneiss at the upper falls of Prairie river.

1524. Coarsely crystalline orthoclastic belts, from the gneiss at the upper falls of Prairie river.

1525. Reddish and chloritic mass wedged in the gneiss at the upper falls of Prairie river.

1525 (a). Spottedness shown on the quartzyte at Prairie river.

1526. Shows another spottedness. Here the rusty spots weather out and produce a pitted surface on the quartzyte; same place.

1527. Hematite and impure hematite, siliceous and jaspery. Prairie river falls.

1528. Rock shown at about the horizon of this hematite.

1529. Somewhat above 1528. Finely laminated or "streamed," also brecciated, jaspilyte, with some vitreous silica.

1530. Jaspilyte and hematite, closely intermixed, but not inter-laminated. The red jaspilyte appears as a felsyte.

1531. Hematite at this horizon; about one-fourth is hematite.

1532. Some of the quartzite that underlies this ore is conglomeritic in patches.

1533. Red shale. Griffin's camp, N. E. ¼ Sec. 22, 56-24.

1534. Iron-bearing rock. The ore impure and in broken and irregular sheets; hematite.

1535. Same as 1534. Pit No. 2, but struck at 15 feet below the surface.

1536. Same as 1534. Pit No. 3. Struck at one foot below the surface.

1537. Slaty hematite, rather low grade (47 p. c. iron) N. W. ¼ N.W. ¼ Sec. 21, 56-14.

1538. Magnetic iron ore, Sec. 23, 60-23. Fleck's location; from John Beckfelt.

1539. Rock associated with 1538.

1540. Duluth; on the Weller road, about 1½ miles from lake Superior, but about 2 miles from the business part of Duluth. Gray, porphyritic gabbro, with a fine magma.

1541. Shows contact of the "red rock" on the gray rock 1540.

1542. Red rock, crystalline. with some light-green spots, from the Weller road, same place as 1540.

1543. Granular silica, appearing somewhat as if originally chalcedonic (see 519). Same place.

1544. Vein matter in gabbro, at Rice's point.

1545. Serpentinous vein matter in gabbro at Rice's point.

1546. Quartz crystals lining vugs in dense hematite. Lee mine, near Tower.

1547. Reddish, earthy-looking jaspilyte. Lee mine.

1548. Breccia of fine pieces of hematite, red jasper and quartz, somewhat stratiform. Lee mine.

1549. Tarnished hematite, appearing as if it might be some copper sulphide; Lee mine. Coatings; Lee mine.

1550. Finely banded (sedimentary?), whitish jaspilyte; Lee mine.

1551. Hard hematite, with included crystals of chalcopyrite.

1552. Piece of chalcedonic quartz mass, embraced in a boulder of Stuntz island conglomerate (agglomerate), near the Lee mine.

1553. Piece of gray quartzose pebble or gray "felsyte," contained in the same boulder as 1552.

1554. Pebble from the same boulder containing vitreous quartz.

1555. Matrix of this boulder containing the above pebbles.

1556. No. 1553 becomes porphyritic in 1556.

1557. Light colored graywacke, or novaculyte, greenish white, with distinct grains of glassy quartz: at the railroad just south of Tower pit (Nos. 8 and 9). Dips N. about 75°—80°.

1558. Green schist, south of the Stone mine, at the railroad cut.

1559. Interbedded jaspilyte in 1558.

1560. Fine grains of disintegrated white jaspilyte; dump of the Stone mine.

1561. Breccia of jaspilyte and of hematite cemented by chemical silica; dump of the Stone mine.

1562. In the dump of the Stone mine some of the quartz crystals are superficially roughened and corroded—some of the fine crystals. What caused it?

1563. Green shale breccia; from the dump at the scram southwest of the Breitung mine.

1564. Botryoidal limonite on quartz crystals and on hematite; same place.

1565. Flinty, gray to dark gray jaspilyte, from the dump of the hoisting-shaft of the same place. Compare 866 B. and 1277.

1566. Rotted, angular masses of jaspilyte as intersected by the water-bearing course of a joint crossing a mass of contorted jaspilyte, at the Breitung mine.

1567. Pebbly conglomerate, embracing small grains of vitreous quartz; a patch or belt in otherwise typical jaspilyte. In the ridge that remains separating the Breitung from the Tower mine.

1568. A jaspilyte egg, somewhat concretionary, at least indistinctly concentric in some color bands. From the cut made for the high tunnel running south from the Tower pit (No. 9), where it crosses the light "ore streak."

1569. Coarse graywacke, rather soft, taken from the roof of the same tunnel, crossed by some thin veins of chalcedonic silica, about 15 feet from the southern entrance.

1570. From the dump, Breitung mine. What is the fine red mineral in crystals?

1571. Siliceous "green schist" interbedded in jaspilyte north of the Tower mine.

1572. From the jasper at the east end of the Stuntz mine. What is the white cementing vein-mineral? It appears to be granular silica, but also shows apparently cleavage surfaces.

1573. Gray gneiss, the rock at North Bay, on lake Nipissing, Ontario, in general, after the weathered surface is removed.

1574. Reddish-weathered gneiss, a surface condition of the rock at North Bay, Canada.

1575. Micaceo-hornblendic, garnetiferous rock embraced in No. 1573, as foreign masses, some of them fifteen feet across.

1576. Hydro-micaceous schist, silky-sericitic, from the "Huronian" at Wahnapitae, Ontario.

1577. The rock that contains the nickel ore at the Stobie mines, near Sudbury, Ontario, a gray quartzyte resembling the Pewabic quartzyte of Minnesota. Compare 1322 and 1340.

1578. The ore from the Stobie mines, Ontario.

1579. The "hornblendic rock" from the dump of the deep shaft which was abandoned at the Stobie mine, Ontario.

1580. Orthoclase found in veins in 1579.

1581. The dioryte dike which is supposed to cut the country rock at the Copper Cliff mine, Ontario. With this the ore is in some way associated.

1582. Ore of the Copper Cliff mine.

1583. Red felsyte, adjoining 1581 on the north.

1584. The conditions of the mined rock and the sulphides at Copper Cliff mine, Ontario.

1585. Matrix of a coarse conglomerate with boulders of red-weathering felsyte, one-quarter of a mile east of the Copper Cliff mine, north of the railroad.

1586. Porphyritic rock, the disseminated crystals being of hornblende and coarse. At the railroad cut, a mile and a half from Sudbury, toward Ohnaping.

1587. Dike-rock, cut by the grade, near the same place.

1588. Somewhat granitic felsyte, enclosing masses of dark basic rock in a manner like those at North Bay; reddish weathering; a quarter of a mile further toward Ohnaping.

1589. Ore of the Murray mine, Ontario.

1590. Black slate, Vermilion river, at the railroad crossing.

1591. Calcareous "concretions" in the black slate at Vermilion river. Same place.

1592. Slate conglomerate, N.W. from Vermilion river; from a ridge that rises perhaps 150 feet above the railroad.

1593. A mile and a quarter east of Algoma, on the north shore of lake Huron. Green slate, dipping S. 10°, W. 45°-65°.

1594. A mile and a half east of Algoma. Roofing slate, gray to black.

1595. Slate conglomerate, 3d of Logan's map. Underlying 1594.

1596. Soft argillyte, with lenticular spots and laminations of chalcedonic silica, next east of the slate conglomerate of 1595.

1597. Supposed chalcedonic silica, from 1596.

1598. Fine grained quartzyte, about 4 miles east of Algoma.

1599. From the great "slate conglomerate" east of Algoma, at a point east of the last.

1600. Fine-grained, nearly black, mica schist; at a mile and a half east of the last.

1601. Crumpled, white, apparently chalcedonic silica, from some argillitic beds east of 1600.

1602. Coarser quartzyte, still farther east.

1603. Dike-rock, cutting conglomerate.

1604. Hornblendic schist, Cooks Mill, at mouth of Serpent river.

1605. Diabasic boulders, with coarse feldspar crystals. Found at Algoma (compare 601).

1606. Quartz-pebble conglomerate boulders. Algoma Mills.

VII.

AMERICAN OPINION ON THE OLDER ROCKS.

CONTENTS.

With incidental citations from Chester Dewey, W. W. Mather, L. Vanuxem, James H. Safford, William B. Rogers, Alexander Murray, J. J. Bigsby, J. Barrande, A. R. Selwyn, J. B. Marcou, Robert Bell, L. W. Bailey, Thomas Macfarlane, J. W. Dawson, C. T. Jackson, J. W. Foster, M. E. Wadsworth, C. R. VanHise, T. C. Chamberlin, James D. Dana, Charles D. Walcott, and others.

By ALEXANDER WINCHELL, LL.D., F.G.S.A.

INTRODUCTION.

As preliminary to a careful inquiry into the nature, arrangement and geological history of the older rocks of North America, I desire to collate the views which have been recorded by competent geologists during the last half century. Such a synopsis of opinions which have marked the progress of our science and have brought it through many labors, conjectures, errors and successes, to the very creditable position which American geological science holds at the present day, will greatly facilitate the work which remains to be done, by placing within convenient reach, the chief data of such progress, with copious references to the documents from which the information is drawn. Such a compendium of historic data will prove especially useful to geologists who have not the leisure to look up and digest the original documents. Since however, compilations of opinion, though offering opportunities for condensation, and even improved lucidity of statement, must necessarily lie under the suspicion that the author's view has been presented with incompleteness or with unintended coloring, the writer has deemed it best to present opinions generally in the exact language of their authors.

The present attempt bears some resemblance to that of Messrs. Whitney and Wadsworth in "Azoic system"*; but it will readily be seen to have a different aim, and to produce results far from identical. Their controlling purpose was, to prove, from citations, that during the time which has elapsed since the "Azoic System" was proposed by Foster and Whitney, no facts have been reported rendering it necessary to conclude that the "Azoic System" as conceived by them, is not both azoic and indivisible. My purpose involves an examination of such a position, but it involves much more. I propose to adduce the facts without the influence of an unalterable predetermination. I propose to select them impartially—rather in the interest of the writers than in the interest of any theory. I propose to give them an unbiased interpretation or to leave them without comment, to be interpreted by the reader. Beyond all this, it is proposed to cite many opinions not bearing on questions of taxonomy and nomenclature—opinions on all subjects whose agitation has taken part in the progress whose fruits we en-

*J. D. Whitney and M. E. Wadsworth, *The Azoic System and its proposed subdivisions*, Bulletin of the Museum of Comparative Zoology, Geological Series, Vol. I, pp. xvi and 331–565.

joy—problems of structure, superposition, metamorphism and geognostic evolution in general.

The method of Whitney and Wadsworth is geographical; mine may be denominated personal; neither traces consecutively the evolution of an idea or concept. Concrete methods have peculiar uses; and it is hoped the method here pursued may be useful as complementary to theirs, even if its subject matter possesses fewer advantages than I anticipate.

In some of these respects the method of the following sketch resembles that of Dr. Hunt in his Historical Introduction to the Azoic Rocks*. It differs, however, in the important feature of giving the views of investigators in their own language. One does not feel certain, in reading the memoir of Dr. Hunt, that he gets exactly the meaning of the original statement. In some cases, it is certain, the meaning is inadvertently colored, or even reversed. Dr. Hunt's treatment also, seems to the writer, deficient in method. It lacks consecutiveness; it abounds in repetitions; the connection of parts is more verbal than logical. The order would seem rather to be that of association of ideas in the author's mind than one determined by the logical or historical relation of topics. For such reasons, it is difficult to follow and comprehend. However this may appear to others, it seems certain that comprehension and clearness of conception must be facilitated by following the growth of conviction in each investigator's mind separately—introducing the biographical element into the history of geological ideas.

In the history of this advance, it has been the fortune of some to observe nature in the field, of others, in the laboratory, of still others, to collate records in the library—and I need hardly remind the reader that the efforts of many others have been expended in provinces not entered in the present discussion. Those who have worked in the field have supplied the greatest volume of records suitable for use in the compilation which follows.

In attaining the status which has been achieved, there must have been many false steps taken—erroneous observations, false interpretations, hasty generalizations, untenable suggestions, ill grounded theories, all mingled from time to time, with the influence of the "personal equation." Still, it is safe to assume that every investigator has been actuated by a controlling love of truth, and has done perhaps, as well as any other investigator would have done in precisely the same circumstances. If any have lost patience with

*Report E, Second Geological of Survey Pennsylvania.

a fellow-worker, it is profitless to reproduce the sarcasm in which impatience has found relief. The language of scorn or contempt has contributed nothing to the noble progress which we contemplate.

As intimated, the present summary of opinion sustains a special relation to the contemplated sequel of the present memoir. Whatever its separate value may be, its use to the writer consists in the light which it sheds on an investigation to a large extent original. Circumstances have turned the writer's attention, during a few years past, toward the study of the older rocks. Though from boyhood familiar with the forms and aspects of the crystalline and sub-crystalline masses of Dutchess, Litchfield and Berkshire counties; though officially connected with public surveys over the crystalline expanses of Michigan; though long since a student of similar rocks in Missouri, Massachusetts and Maryland, it is true that the present research has been in a field comparatively new, and conducted by methods in part unknown to the older investigators, and but imperfectly mastered by most of us. It has seemed to the writer that one of the fields in which he has studied presents the problem of the older rocks under simplifications which promise advantages not enjoyed by the older students of terranes of high relative antiquity. Perhaps he deceives himself in thinking these advantages have brought him—a comparative novice—into possession of glimpses of truth which have been hidden from abler, but less fortunate students. He hopes however, the result will justify his confidence.

EBENEZER EMMONS.

1824. Ebenezer Emmons, in 1824 a pupil of Dr. C. Dewey, was associated with the latter in the preparation of a geological description and map of Berkshire county, Massachusetts, and of a small part of the adjoining states.* In this description the rocks are arranged in the following order (the whole being here inverted):

3. Transition limestone, &c.
2. Quartz, Primitive limestone, Primitive argillite (Upper Primary).
1. Granite, Gneiss, Talcose slate, Mica slate (Primary).

The second division indicates the elimination of the "Taconic idea" eighteen years before it received a formal designation.**

*American Journal of Science and Arts, Vol. 8, 1824, pp. 1, 240. An abridgement of this was included in "A History of Berkshire County," in 1829.

**1819. In a "Sketch of the Mineralogy and Geology of the vicinity of Williams College" (Amer. Jour. Sci., Vol. i, p. 327, ii, 246, 1820.) Dr. Dewey had already published the germinal conception of the above arrangement, and of the Taconic system. The rocks and minerals were arranged in the following order: 1. Granite. 2. Gneiss and Mica

1837. At the end of the first season's observations within the Second Geological District of New York, professor Emmons described the rocks, in the nomenclature of the day, as Primitive, Transition and Tertiary.* Under the first, he describes first, Granite, which is "not strictly speaking, granite; that is, it is not composed of quartz, feldspar and mica; neither is it a true sienite, for even the hornblende disappears almost entirely for miles. It is mostly feldspar. . . . It contains the beautiful Labrador feldspar . . . often in large masses. . . . The color of the rock is usually grey, greenish or bluish. . . . It rarely contains quartz. . . . In Essex county it forms mountain masses. . . . The other primitive rocks of the northern counties are gneiss, hornblende and granular limestone. The talcose and mica slates rarely occur." The following is the succession reported, arranged here in descending order:

TERTIARY, consisting of grey sand and marly clay, with shells of recent aspect.

TRANSITION ROCKS. 1. Calciferous sandrock, including Potsdam sandstone. 2. Transition or blue limestone.

PRIMITIVE. Granite, Gneiss, &c.

1838. Professor Emmons again ranges the rocks of St. Lawrence county as Primitive, Transition and Tertiary†. The Primitive region he also designates "the gneiss district," but he states that "the rock is not purely gneiss," but only "the predominant rock," the region embracing also "granite, limestone, sienite, hornblende, steatite, serpentine, &c." The granite, he says, "occurs in beds and veins subordinate to the gneiss; . . . in huge angular beds or protruded masses; in the form of veins branching irregularly into the adjacent rock, and in overlying masses analogous to overflowing lava currents or greenstone." He speaks of it as sometimes "interlaminated with gneiss or other rock," but considers such position "accidental" (p. 196). The granite and gneiss contain in places, more or less carbonate of lime, or of lime and magnesia. The "primitive limestones" he speaks of as interstratified, but is particular to discriminate them from the marbles of Vermont and Massachusetts, "especially those of Berkshire county."‡ He gives eleven diagrams to illustrate the position that

slate. 3. Quartz. 4. Granular limestone. 5. Argillaceous slate. It will be noted that there is one limestone formation. These views were adopted by Prof. Amos Eaton in his "Index to the Geology of the United States," 1820, though later, he became an indefatigable original observer. (*Amer. Jour. Sci.*, xiv, 147, 1828.)

**First Annual Report*, New York, 1837, Assembly, No. 16, pp. 109-117.

†*Second Annual Report*, New York, 1838, Assembly No. 200, pp. 194-217.

‡This is further insisted on, p. 232.

we have the same evidence of the igneous origin of the primitive limestone as of the igneous origin of granite—that is, it occurs interbedded, penetrating and ramifying in relation to the granite.*

The sandstone at Potsdam is said to rest directly on the primitive rock, but it is no longer identified with the "Calciferous sand rock" of Eaton, (p. 214). On page 217, it is called for the first time, "the Potsdam sandstone" (pp. 217, 230.)

Treating of Essex county he speaks of the granite as "composed essentially of Labrador feldspar and hypersthene," and decides to style it "Hypersthene rock" (p. 220). It contains extensive beds of iron ore, sometimes branching and vein-like. The primary limestone "uniformly occurs in veins" in the hypersthene rock. The gneiss of the country is limited in extent, is interlaminated with saccharoidal limestone, and contains beds of magnetite and hæmatite (p. 221).†

We have no documentary evidence of the progress of the evolution in Dr. Emmons' mind previously to the publication of the Gazetteer next to be mentioned. But professor Dana has recorded the fact‡ that, according to information from professor James Hall, a discussion of "Taconic ideas" took place at the meeting of the "Association of American Geologists and Naturalists" at Philadelphia, in April, 1841. In this, Dr. Emmons was opposed by H. D. Rogers, E. Hitchcock, W. W. Mather and James Hall, while Lardner Vanuxem favored his views.‖

*Numerous other reputable geologists have entertained the same rather remarkable opinion—von Leonhard, Giudini and Rozet.

†The Tertiary beds are of some considerable extent, occupying "not only the Champlain valley but that of the St. Lawrence and Hudson also." He notes it as a "marine formation," and states that "above these clays, &c, we have the modern group composed of boulders, pebbles and sands" (238). Emmons here bestows the names "Mt. Marcy" and "Adirondack group" or "Adirondacks"—the latter to embrace the high summits of northern New York. (pp. 242, 243).

‡*Amer. Jour. Sci.* III., xxxvi, 412.

‖The Proceedings of this Meeting are found in the "*Trans. Assoc. Amer. Geologists and Naturalists*, 1840-42, but this discussion not having been reported, no mention of it appears, under a rule of the Association. The proceedings are reported also, in *Amer. Jour. Sci.*, xli, 158, 1841. The grounds of Vanuxem's defence are stated in *Report on the Third District*, 1842, pp. 22-23. He styles it "The Taconic or Intermediate System," and says, "the Cambrian System holds the same position." Mather's reasons for regarding the Taconic rocks as a metamorphic condition of the Champlain rocks are given (p. 438) at the close of a chapter on the Taconic system; also p. 464 (*Report Third District of New York*, 1843, pp. 422-438), Professor Hall in his report on the Fourth District, embraces the Taconic system in his enumeration, and nowhere expresses any dissent.

"The comparison of views at the meeting", says professor J. D. Dana, (*Amer. Jour. Sci.*, III., XXXVI. 413, Dec., 1888) "resulted in inducing Prof. Rogers and Prof. Hall to take the field for the study of sections over the Taconic region. The season had just passed when Prof. Rogers made a report on his results to the American Philosophical Society at Philadelphia (*Proc. Amer. Phil. Soc.*, Jan., 1842) sustaining the views which Hitchcock, Hall, Mather and himself had before favored".

1841. A communication appeared from Dr. Emmons on "The Geology of Montmorenci,"* which, according to Dr. Selwyn, "seems to be of considerable interest and importance, in view of recent discussions." It supplies some of the evidence on which Dr. Emmons determined the existence of a great fault, reaching from the St. Lawrence into Vermont and New York. On the highway from Quebec to the falls, at the Beauport river, a regularly bedded, horizontal, nearly black limestone outcrops, "presenting a remarkable contrast with the highly inclined rocks of Quebec." A "black slate," also, "apparently rests against" the limestone. A fault or uplift is thought indicated by the facts here observed," along the line which the road passes." The first outcrop is" very clearly Trenton limestone," and "the slate is the Hudson River slate."

At the fall, the bed of the river above, is gneiss. Reposing horizontally on its edges, is, first, the Potsdam sandstone, stained with copper, and not over ten feet thick; second, coarse bowlders, as at Chazy, N. Y., considered the upper portion of the Potsdam; third, "a compact limestone" conformably overlying, containing encrinites. This "graduates into a gray, crystalline limestone," with broken encrinites. Succeeding this is the Trenton, 60 or 70 feet thick. The absence of the Calciferous and Chazy is noted; though this is not considered remarkable.

Below the fall, the rock forming the fall is seen to be fine-grained gneiss. Against this, the Black slate of the Hudson river reposes, but with an unconformable inclination. Dr. Emmons recognizes here a fault, with an uplift on one side "and a down heave on the other, by which the slate has been thrown into an inclined position."

This fault is regarded as extending south along the Beauport road, and even into the state of Vermont; and "may be particularly traced on a line connecting Johnson's mountain in Lower Canada, several points on the Missisque bay adjacent to the Provincial line, and also, at the remarkable uplift at Snake mountain, in Addison, Vt. A line uniting those points and several others in the same direction, marks the line of a great disturbance which has deranged the lower Transition rocks for at least four hundred miles."

In view of these facts, Dr. Emmons asks; "May not the great fault have caused the confusion in the writers on geology, in re-

*The *American Magazine*, November, 1841. See this reproduced in *American Geologist*, ii, pp. 94-100, August, 1888. The date of this paper was wrongly printed in the *American Geologist* at first, but was corrected afterward (vol. iv, p. 387).

gard to the lower Transition rock, particularly the Hudson River slates and shales? May not the same derangement exist in England and Wales, and have been the cause, at least in part, of their separation from the Silurian system, and of their being considered as one distinct therefrom, and which has been called the Cambrian System?"

He speaks of the horizontal position of the Hudson River rocks at Pulaski, Lorraine, Rodman and Pinckney, in New York, conformable with the Silurian system; and of their inclined position in Rensselær and Washington counties, in Vermont, and the entire length of Lower Canada. In the latter region, they agree with the Cambrian (omitting the lower portion.) He speaks of this as a conviction of long standing.

He continues: "It is proper to notice here one source of difficulty in regard to the rocks of the Hudson river, especially on their eastern border. It is the fact of their overlapping in this direction, the Trenton limestone and the other Transition rocks beneath. The consequence has been that, in traveling from east to west, or from Massachusetts and Vermont to New York, we pass directly from the Primary mass to the higher members of the Transition system; consequently they [geologists] have placed them upon the Primary, and considered them as the lowest of the Transition; whereas there intervenes between the Hudson river slates and the Primary, the Trenton limestone, the Birdseye, Calciferous, and Potsdam sandstone, the aggregate thickness of which exceeds a thousand feet. Not one of the lowest members of the Transition system appears in the eastern prolongation, between the Highlands of the Hudson and the Highlands north of Quebec, adjacent to the Primary, in consequence, as has already been said, of the overlapping of those rocks formerly termed Greywacke, or now known as the Hudson river series, to the talcose slates of the Primary, and also, the great correspondence in kind and amount of their dip."

Speaking of the tenuity of the Hudson River rocks where found horizontal, and their great thickness where inclined—amounting to 20 or 25 miles—he says:—"There can be no doubt that east of the Hudson, there are numerous repetitions of the same layers; for it cannot be supposed for one moment, that any of the formations above the Primary, can be of this enormous thickness which observation seems to indicate."

1842. While occupied in the preparation of his final report on the Second District of New York, Dr. Emmons drew up an article on the "Topography, Geology and Mineral Resources of the State

of New York", which was published in March, 1842.* In this article he says: "The rocks (upon the eastern border of New York, adjacent to Vermont, Massachusetts and Connecticut) are situated between the gneiss of Hoosick mountain on the east and the slates of the Transition on the west. They occupy, therefore, geographically, as well as geologically, an intermediate position–the rocks on the one hand bearing a very close resemblance to the Primary on the east, and on the other, a great similarity to the Transition slates on the west. Still, as a whole, the rocks of the Taghkanic range may generally be distinguished from those on either side, their general character being derived from the presence of a large proportion of magnesia, which imparts to the rocks a softer feel and a peculiar greenish color. It is not proposed in this plan, to separate these rocks from the Primary, but to consider them as belonging to the upper portion, and to speak of them as the Taghkanic rocks, or perhaps as the *Taghkanic System*. . . Considering them for the present, as belonging to the upper portion of the Primary, the Taghkanic rocks will be composed first of a peculiar talcose slate, or a magnesian slate in part; in other parts, it is plumbaginous, which strongly soils the fingers. . . Second, of white, gray and clouded limestone, varying in texture from fine to coarse-granular, often interlaminated with slate, the latter often merely coloring the limestone, so as to impart that clouded appearance . . . Third, of granular quartz, or a sandstone generally silicious and of a brown color . . . The whole *Taghkanic System* is clearly stratified, and is wholly unconnected with gneiss, serpentine, granite, sienite, steatite or hornblende . . . "

This distinct announcement of the Taconic System, it will be observed, appears in a volume printed in March, 1842. It must have been drawn up, probably, some months previously. Professor J. D. Dana, by a slip extraordinary for him, has quoted a passage from Mather's Fifth Annual Report†, the meaning of which is that the writer, on January 20, 1841, (Dana says Febuary 1, 1841), regarded the "granular quartz" (embraced in the Taconic) as simply "the Potsdam sandstone in a metamorphic state", and the associated "granular limestones" as belonging to the same geological epoch", and that "the rocks generally along the eastern border of New York, and probably all the rocks from the New York State line east to the Connecticut valley are similar". But these, it appears, were not Emmons' views on the first of February, 1841. The

*A *Gazetteer of the State of New York*, etc., Albany, 1842. J. Disturnell, March, 1842, p. Attention has been called to this and other early literature bearing on the Taconic system, by Lieut. A. W. Vogdes, in the *American Geologist*, vol. II, 1888, pp. 352-55.

†*Amer. Jour. Sci.*, III, XXXVI, 411, beginning, "The granular quartz of Bennington", &c.

conception of the Taconic system was not originated in the brief period between this date and January 1, 1842—the date of Emmons' final report. The citations already made from the geology and map of Berkshire county show that the body of rocks between the Primary granites, gneisses and schists, and the Transition rocks above, had been isolated eighteen years before, though at that time designated "Upper Primary". If Emmons made no mention of them in his annual reports, it was because they were not embraced in his district. In a final report, however, he tells us he felt constrained to carry into effect a plan formed in the beginning of the survey, "to furnish the materials necessary for a complete work on the New York rocks" and to make "this volume distinct from, and independent of, the reports of the other districts"* In another connection he informs us that the conception of the Taconic dates from 1838.**

In his Final Report on the geology of the Second District,† Dr. Emmons gave the following classification of the Primary rocks:

I. UNSTRATIFIED.	II. STRATIFIED.	III. SUBORDINATE.
1. Granite	1. Gneiss.	1. Porphyry.
2. Hypersthene rock.	2. Hornblende.	2. Trap.
3. Primitive limestone.	3. Sienite.	3. Magnetic, and
4. Serpentine.	4. Talc or Steatite.	4. Specular oxide of iron.
5. Rensselærite.		

The granites are recognized as erupted at different epochs. The hypersthene rock contains disseminated grains and extensive beds of magnetite (p. 222). The primitive limestone is still regarded as unstratified and igneous in origin (pp. 38, 225). Adverse opinions are examined, and new evidences adduced. Serpentine is also alleged to be never stratified, and to have been erupted, probably, at different epochs (pp. 69, 70). Yet it never occurs in dikes or veins, and causes no alteration in contiguous rocks. The same opinions are entertained of Rensselærite (p. 74). "The term sienite is applied to a stratified rock composed of feldspar and hornblende" (p. 80). The magnetic and specular oxides of iron are regarded as of igneous origin (p. 97). Of the origin of the stratified primary rocks nothing is here recorded.

The seventh chapter of this volume (pp. 135–164), is devoted to the "Taconic System," though none of the rocks have been observed to occur in the Second District of New York. "A large portion of its rocks or masses are interlocked between the New England or primary ranges upon the east, the most important of which

*Report, Second Dist., 1842, p. 135.
**American Geology, Pt. II, pp. 5 and 6.
†Geology of New York, Part II, 1842, p. 23. This was published May 26, 1843.

is the Hoosick mountain, and the Taconic (range), with the more westerly abrupt hills, upon the west—or the eastern border of the New York Transition system." On each side, the rocks partially blend with the contiguous systems. The lower limit of the Taconic system is the upper limit of the Primary. The statement that "these rocks belong to the earliest deposits" (p. 141) would imply that gneiss (of the Primary) is not regarded as sedimentary in origin*. The upper limit of the Taconic system is the Potsdam sandstone—which at this epoch was regarded as the base of the fossiliferous series, or at least of the Silurian series.

The formations here embraced in the Taconic system are the following, in descending order:

5. Stockbridge limestone, coarse granular and of various colors.
4. Granular Quartz rock, generally fine grained and brown, but sometimes white, granular and friable.
3. Magnesian slate having a soft feel. Principal mass of Taconic mountains (p. 153). Perhaps repeated in Greylock mountain, on the east of the Sparry limestone.
2. Sparry limestone.
1. Taconic slate, at the western base of the Taconic range, adjacent to the Hudson River shales.

The order of superposition, however, is not regarded as settled (p. 150).†

This is what Dana calls Phase I.

It is difficult to appreciate the reasons given by Dr. Emmons for placing his Taconic slate at the bottom (supposing this is what he means)—even in the light of his own section from Adams, Massachusetts, westward to the Champlain rocks of New York (given on p. 145). It is true the beds have a general dip eastward, giving the "Taconic slate" the appearance of dipping under all the other members; but the "Taconic slate" lies contiguous to the Champlain rocks, and even extends under them, though apparently by an overslip of the latter.

It is a singular inconsistency of Dr. Emmons, that in explaining the distinctions of the four limestones from the Primary to the Champlain, he expressly ranges the "Sparry limestone" above the "Stockbridge limestone" (p. 142)—an order which he was destined later to accept for the whole Taconic series. Similarly, (p.

*"Dividing the rocks into two classes, the primary and sedimentary" (p. 290) he says, elsewhere. See also p. 416.

†There are some indications that the order intended by Emmons is the reverse of this. So Mr. Marcou has understood him, in "The Taconic system and its position in stratigraphic geology" (*Proc. Amer. Acad.*, xii, 174-256. 1885.)

142) he places the "magnesian slates" below the "fine aluminous slate ("Taconic slate,") an order which he immediately, but with apparent unconsciousness, reverses (p. 144) and, though somewhat hesitatingly, defends (p. 147).

The Stockbridge limestone must be distinguished from the Primary limestone below, and the Sparry limestone must not be confounded with a silicious limestone occurring in the "Champlain group" above. Similarly, "the "Magnesian slate" must be distinguished from the lower Talcose slate of the Primary, and the Taconic slate must not be confounded with the shales and slates of the Hudson river. The Taconic rocks are entirely destitute of fossils; but "they furnish us with a knowledge of that state which immediately preceded the existence of organic beings" (p. 164). They are regarded as "equivalent to the Lower Cambrian of Professor Sedgwick," "the upper portion being the lower part of the Silurian system."

In the "Tabular Views" of the sedimentary rocks of New York (p. 429), the members of the Taconic system are given as follows:

4. Granular Quartz [=Potsdam sandstone.]
3. Stockbridge Limestone [=Blue limestone of Hudson Valley.]
2. Magnesian Slate [=Slates of the lowest formation of the Appalachian System.]
1. Taconic Slate.

I have placed at the right in brackets the equivalences of the Taconic members as maintained by professor H. D. Rogers, in 1844.*

It will be noticed that the relative positions of the Granular Quartz and Stockbridge limestone here are the reverse of those given near the commencement of this report. Also, the Sparry limestone is omitted.

1844. Dr. Emmons issued a thin quarto volume entitled "Taconic System," and dated December 2, 1844, containing the results of the previous two years of study. The Taconic system appears with important changes and an extension of area. The contents of the memoir were exactly reproduced (except the Preface) in his Report on the Agriculture of New York.†

1846. In the first volume of his Report on the Agriculture of New York,‡ he devotes the fifth chapter (68 pages) to a fresh dis-

* In May, 1844, Prof. H. D. Rogers returned to a discussion of the Taconic system, in his presidential address before the Association of American Geologists and Naturalists at Washington (*Amer. Jour. Sci.*, xlvii, 137, 247, 444). He seems to have been the first to suggest that the Potsdam sandstone might not be the absolute base of fossilization among Amer can rocks.

†*The Taconic System, based on observations in New York, Massachusetts, Maine, Vermont and Rhode Island.*

‡*Agriculture of New York*, vol. 1, 1746. p. 55.

cussion of the Taconic system. Stimulated by the opinion of the brothers Rogers, accepted by Mather, E. Hitchcock and Dr. Samuel L. Dana, that the Taconic rocks were merely metamorphic conditions of the lower members of the New York or Appalachian system, he resumes, with new facts, a presentation of evidences sustaining his former positions, 1st, that the Taconic rocks are "inferior to the Champlain division of the New York system, or the lower division of the Silurian system of Murchison (p. 55); 2d, That they are a series of sediments reposing directly on the Primary system; 3d, That they contain previously unknown organic remains; 4th, That the lithologic members of the Taconic system have a different order of arrangement from that found within the New York system, and are much thicker than those to which they have been supposed equivalent in that system. The members of the system, as now recognized, are as follows:

6. Black slate (hitherto included in Taconic slate), with *Atops trilineatus* and *Elliptocephalus asaphoides*. I.
5. Taconic slate (with seven subdivisions), including Hoosick roofing slates with *Bucoides* and *Nereites*. III.
4. Sparry limestone (of Eaton). II.
3. Magnesian slate of Taconic and Saddle mountains.
2. Stockbridge limestone, in the Hoosick and Housatonic valleys, and extending to Sing Sing.
1. Brown sandstone or Granular Quartz, with four subdivisions.

This is what Dana calls Phase II.

The Sparry limestone is here replaced, the Black slate is separated from the Taconic slate, and the whole series is turned upside down. This order is now in accordance with the indications of the section given on page 145 of his Report on the Second District, and conforms with the theory of an overturn, as maintained by H. D. Rogers.

In this volume, the Taconic is recognized in Rhode Island, in Maine and in Michigan.

In another publication of about the same date* he makes a historical remark on the origin of the Taconic system, referring to the article in Disturnell's State Register. "In making up our notes for this object," he says, "we found it necessary to fix upon some general subdivisions of the rocks belonging to the State. We drew up an abstract of the plan, and submitted it to the criticism of the Rev. Prof. Dewey, of Rochester. . . . Professor

***American Quarterly Journal of Agriculture and Science*, vol. iv, 1846, p. 202.

Dewey approved of the division proposed, in the main. It resulted in separating the rocks in the vicinity of the Taconic range, both from the Primary and the New York Transition, as we then called them.

1848. Professor James Hall having described* *Atops trilineatus* of Emmons under the name of *Calymene beckii*, and referred it to the Hudson River group, and having also described in the same work (p. 256) *Elliptocephalus asaphoides* under the name of *Olenus asaphoides*, and referred it likewise to the Hudson River group (see especially Hall's foot-note, p. 257) professor Emmons, "with other specimens more perfect" presented to the American Association, a new and detailed description of *Atops trilineatus*, and a parallel description of *Triarthrus* (*Calymene*) *beckii*† pointing out what appeared to be important differences‡. He also discussed *Elliptocephalus*, and indicated technical distinctions between that genus and *Olenus* and *Paradoxides* (p. 18). In the same connection he repeated that the tenability of the Taconic system rested on structural and mineralogical evidence "far more important than the presence or absence of certain fossils"—meaning evidently, these fossils.

1855. In his "American Geology," the second part of which appeared this year,|| the Taconic system receives a new presentation. The following is a synopsis of the System as then understood:

Upper Taconic.	Black slate of Bald mounìain,	I. Cambrian.
	Taconic slate,	III. I. Hudson slates and Cam.
Lower Taconic.	Magnesian slate,	III. Hudson slates.
	Stockbridge L. includ'g Sparry L.	II. Lower Silurian.
	Granular Quartz.	I. Cambrian.

(I have added on the right, the equivalences as laid down in 1888, by professor J. D. Dana).

This is styled by professor Dana, Phase III; but the only change made since Dr. Emmons' last publication is the omission of the "Sparry Limestone," as in the "Tabular View," at the end of his Report on the Second District—this being merged in the "Stockbridge Limestone,"—and the recognition of a division of the system between the fossiliferous and the unfossiliferous portions—giving us "Upper" and "Lower" Taconic. There were two reasons

**Palaeontology of New York*, vol. i. p. 252., pl, lxv, figs, 4a-e.

†*Proc. Amer. Assoc.*, 1848, pp. 16-19.

‡ In his judgment of lack of identity, he had been sustained by S. S. Haldeman, chairman of a committee of the Association of American Geologists and Naturalists, a pointed to consider the question (*Amer. Jour. Sci.* II, v. 117, 1848). This judgment fessor Hall opposed (*Amer. Jour. Sci.* II, v, 322, 1848.)

|| *American Geology*, Part II, 850 pp., Albany, 1855, pp. 1-122.

for inverting the order as originally given : 1st, evidence of an overturn, as all along argued by Rogers, and as shown by the diagram given by Emmons himself ; 2d, the discovery of fossils in the Black slate, which Emmons had always merged in the Taconic slate, or had closely associated with it (*Ag. Rep.*, *63*). Thus the Black and Taconic slates now stood at the top, but their close chronological association was an erroneous assumption—the former only belonging truly to the sub-Potsdam series. As Dr. Emmons excluded the Potsdam sandstone from the Taconic, and as the Granular Quartz has proved to be Potsdam sandstone, the Black slate was all that he had thus far really brought into the sub-Potsdam Taconic. This Black slate of Bald mountain, Rensselær county, was now the only imperishable nucleus of the Taconic system as conceived—however Dr. Emmons believed. The so-called Lower Taconic was pronounced azoic.

The following points taken from the "American Geology" (p. 122) embody the most important features of the system as then understood by its author: 1. "Its series divided into groups are physically unlike the Lower Silurian series; 2. "It supports unconformably at numerous places, the Lower Silurian rocks." 3. "It is a vital system, having been deposited during the period when organisms existed"; 6. It "carries us back many stages further in time, when life gave vitality to its waters, than the Silurian." To the Bald mountain locality of trilobites he here added one in Augusta county, Virginia, from which he described *Microdiscus quadricostatus*. He also described four marine plants, 22 graptolites and six molluscs.

Keeping in mind the black slate of Bald mountain, which had yielded two species of trilobites regarded by Emmons as sub-Potsdam in age, though described by Hall as of Hudson River age, it is interesting to note the discovery, about this time, of other trilobites in the Black slates of West Georgia, Vermont, lying within the region claimed by Emmons as Taconic. These falling, after two years, into the hands of professor Hall, were also described by him* as belonging to the Hudson River group. By this authority the beds were thus made equivalent to the Bald mountain Black slate. The names given these trilobites were *Olenus thompsoni*, *O*, *vermontana* and *Peltura holopyga*, now determined by Walcott as *Olenellus thompsoni* Hall, *O.* (*Mesonacis*) *vermontana* Hall sp. and *Bathynotus holopyga* Hall (*Amer. Jour. Sci.* III, xxxvii, 389, May, 1889). These were new accessions to the real

**Twelfth Ann. Rep. New York Regents*, 1859, 59–62. On the age of the rocks see *Pal. N. York*, vol. III, p. 94; compare also *id.*, p. 83.

Taconic, for, though made Silurian by Hall, they were recognized by Barrande as primordial or sub-Silurian types. A real sub-Potsdam Taconic existed, therefore, in 1854, in Rensselaer county, New York, and in West Georgia, Vermont, not to mention Augusta county, Virginia. That fact was embraced in Dr. Emmons' claim.*

1859. We have no documents of this date from the pen of Dr. Emmons, showing his use of these primordial trilobites as vouchers for the existence of a real Taconic system. We find no recorded views from him on the publication made by Prof. Hall in 1859; but in his Manual of Geology† (p. 88) the preface of which is dated May 1, 1859, a large trilobite is figured under the name of *Paradoxides brachycephalus*, which, as suggested by professor C. H. Hitchcock in 1881,‡ is identical with *Olenus thompsoni* Hall.

This publication antedates that of the *Twelfth Regents' Report.*‖ The evidence is, therefore, that independently of work done by others in Vermont, and before their results were published, Dr. Emmons had become acquainted with, delineated and published sub-Silurian trilobites within the Vermont area over which he had extended his asserted sub-Potsdam Taconic system. The Georgia slates now beginning to yield the palaeontological evidence of their age, were part of the "Primitive argillaceous slate" of professor Dewey;§ the "Primitive argillaceous slate" of Dr. E. Hitchcock;** the "Black slate" and "Taconic slate" of Dr. Emmons in various publications on the Taconic system.

1860. However, in a note at the end of the second edition of his Manual of Geology (p. 280) he says: "The slates or shales referred to (in the *Regents' Report* for 1859) in northern Vermont, as constituting a new series above the so-called Hudson River group, instead of ranking thus high in the geological scale, are really sub-Silurian, as is fully proved by the overlying calciferous sandstone.

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*The Taconic system was maintained in the *Report on the Geological Survey of North Carolina*, 8 vo. 1856, pp. 49–72—reviewed in *Amer. Jour. Sci.* II, xxiv, 427-430.

†*Manual of Geology*, By E. Emmons, 290 pp. 8 vo, Philadelphia, 1860.

‡*Geology of Vermont*, vol. 1, 367.

‖According to Prof. Hall, the whole of the XIIth *Regents' Report* was published previous to Sept. 20, 1859. Mr. Billings gives Oct. or Nov. for the date of publication (*Canadian Naturalist*, vi, 316) though the date on the title page is March 15, 1859—evidently the date at which the printing began. This document purports to be "some of the results of investigations made during the years 1855, '56, '57 and '58 by James Hall" and a note states that they "are already printed in the third volume of the *Palaeontology of New York*." The transmission of this volume to the governor, nevertheless, is dated September, 1859," showing that though "printed," it was not published earlier than the *Twelfth Regents' Report*.

§*Geological Map of Berkshire, Mass; Columbia and Rensselaer counties, N. Y.*, Amer. Jour. Sci., viii, 124.

**Geological Report of Massachusetts*, 1832.

. . . We now know the following trilobites, all of which belong to a slate beneath the Calciferous, viz: *Atops punctatus, Elliptocephalus* (*Paradoxides*) *asaphoides, Paradoxides Thompsoni, P. Vermontanus, P. macrocephalus, P.* (*Pagurus*) *quadrispinosus* and *Microdiscus quadricostatus.*"

This extension and validity were given the Taconic system during the life of Dr. Emmons, and almost wholly through the persistence, ability, and force of his own efforts. The geologists of the country, save Vanuxem, Jewett and Billings, were unitedly against him. The most prominent palæontologist of the country had referred the Georgia trilobites to the upper part of the Hudson River group. The distinguished structural geologist of Canada, Sir William Logan, had rendered his testimony that the shales affording the fossils were "part of a series of strata which he is (was) inclined to rank as a distinct group above the Hudson River proper.* Only one authoritative voice was raised in vindication of Dr. Emmons' long contested claims. That voice came from across the ocean, and almost in tones of reproach for American palæontology, in failing to recognize the principles of order which it had professed to recognize in the succession of organic life, gave utterance to the sentiment: "Si le Dr. Emmons fait encore de la géologie c'est pour lui une belle occasion pour réproduire ses anciennes observations et ses idées avec plus de succés q'en 1844.†

No public documents relating to the Taconic, of later date than 1860, issued from the pen of Dr. Emmons. He went to North Carolina in September, 1860, as State Geologist, and remained within the Confederate lines during the civil war, "until he died, in 1863, at his plantation in Brunswick county, on the first of October". Mr. Marcou, however, maintained a correspondence with him until January 28, 1861, and from these letters I quote a few passages.‖

In a note dated Raleigh, Nov. 10, 1860, he says: "I do not think him (Barrande) right in maintaining that his Primordial Group is a part or parcel of the Silurian . . . The Lower Silurian is strictly unconformable to every part of my Taconic series." Writing the next day, he continues: "Perhaps I did Barrande injustice. . . I find that after all, his Primordial Group is only Lower Silurian. I conceive we have exactly his Primordial Group in the

*Twelfth Report N. Y. Regents, p. 62, note.

†Letter of M. Barrande to M. Marcou, 14th Aug., 1860, (*Proc. Amer. Acad.*, 1885. p. 182) "On the Primordial Fauna and the Taconic System of Emmons." Also, in part, *Proc. Boston Society Nat. Hist.* vii, Dec. 1860, 369-375.

‖The letters are published, with much other correspondence, in *Proc. Amer. Acad.*, xii, 1885, pp. 181-224.

band of slates containing the *Paradoxides*.* On the 28th of December, referring to a communication rejected by the editor of the *American Journal of Science*, in which were embodied some comments on the Huronian system of Logan, he says: "I claimed that the Huronian was only the Taconic system." On January 23, 1861, he writes: "It was ten years ago, I think, when I claimed Logan's Huronian system as nothing more than the Taconic. . . The acknowledgment of the Primordial of Barrande in this country (referring to some concessions of Sir William Logan)† is really one of the finest and best facts in geology, making a co-ordination of American and European rocks so complete and harmonious; I think of nothing I have said or done in this matter; I look upon the harmony of the systems; they are truly worth dwelling upon."

In reference to M. Marcou's proposal to include the Potsdam sandstone within the Taconic, Dr. Emmons writes, January 28, 1861: "Let me declare once for all, that I have not the slightest objection to your view. . . If you believe you can make out a good case with the Potsdam anywhere, I never shall object, for I have no wants except truth."

These noble sentiments close the correspondence, and constitute, so far as I know, the last utterance of Dr. Emmons which passed the lines of a country so soon to become the theatre of bloody war.

Let us now consider the form which the Taconic system had assumed during the lifetime of its author:

Upper Taconic.	Potsdam sandstone (suggested by Marcou, assented to by Emmons).	I. Cambrian.
	Black slate of Bald Mountain and Georgia slates of Vermont.	I. Cambrian.
	Taconic slates.	III. Hudson slates and I. Cam.
Lower Taconic.	Magnesian slate.	III. Hudson slate.
	Stockbridge limestone, including Sparry limestone.	II. Lower Silurian.
	Granular quartz.	I. Cambrian.

*This looks like an admission that Emmons' *Paradoxides* band was Lower Silurian—against which he contended. But though Primordial was Silurian in the extended sense in which Barrande used the term, it was beneath the Silurian as Emmons conceived it. On the previous day he had declared Barrande's Primordial *not* properly Silurian.

†About this time, in a letter to Barrande, dated Dec. 31, 1860, Sir W. E. Logan wrote: "Professor Emmons has long maintained . . . that rocks in Vermont which in June, 1859, I for the first time saw and recognized as equivalent to the magnesian part of the Quebec group, are older than the Birdseye limestone; the fossils which have this year been obtained at Quebec, pretty clearly demonstrate that in this he is right. It is at the same time satisfactory to find that the view which Mr. Billings expressed to you in his letter of the 12th, July, to the effect that the Quebec trilobites appeared to him to be about the base of the second fauna, should so well accord with your own opinions, and that what we were last spring disposed to regard at Georgia as a colony in the second fauna should so soon be proved, by the discoveries at Quebec, to be a constituent part of the Primordial Zone." This, says Barrande (*Documens anciens et nouveaux*, etc. *Bull.* 4 Fev., 1860, p. 320) "is a formal recognition by Sir William Logan, of the Taconic System at the base of the Silurian."

On the right are the parallelisms established by Dana, Walcott and others. The Table shows the Taconic system left by its author in state of incompleteness—even confusion. We find three members whose true positions are above the Potsdam sandstone. But we find also three members whose positions are admitted to be sub-Potsdam—as maintained by Emmons. The mal-position of the Stockbridge limestone was an error of exactly the same magnitude as that of the geologists who would identify the Granular quartz with the Potsdam sandstone, or would make the Black slates of Georgia synchronous with the Hudson River shales. Our science was then in a comparatively crude state, and none of these errors need surprise us. We have ascertained that a real sub-Silurian system exists, and that Dr. Emmons fixed upon three if not four of its members. Such are the facts. Geologists will differ as to the question whether such a degree of success entitles Dr. Emmons to a recognition of the name proposed by him for the real system whose existence he mentally apprehended so well, but whose form he defined so imperfectly.

It is intended to pursue the later history of opinion concerning the Taconic system, as, with the progress of science, the question became more and more palæontological; and if not yet regarded as settled, the discussion is proceeding mainly on palæontological grounds. The principal papers published in the controversy, since the close of the era of the founder—about 1860, will, unless previously quoted, be found cited in the subjoined note.

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*1860. Barrande, Joachim.
On the Primordial Fauna and the Taconic system, with Notes by Jules Marcou. *Proc. Bos. Soc. Nat. Hist.*, Vol. VII, pp. 369–382.

1861. Barrande, J.
Documens anciens et nouveaux sur la faune primordial et le système Taconique en Amérique. Paris, 1861.

1861. Hunt. T. S.
On the Taconic system of Emmons. *Amer. Jour. Sci.* II. xxxii, 427–430.

1861. Hunt, T. S.
On some Points in American Geology. *Amer. Jour. Sci.* II, xxxi, pp. 392–414.

1861. Marcou, Jules.
The Taconic and Lower Silurian Rocks of Vermont and Canada. *Proc. Bos Soc. Nat. Hist.*, Vol. viii, pp. 239–253.

1862. Marcou, Jules
Liste additionelle des fossiles du terrain Taconique de l'Amérique du Nord. *Bull. Soc. géolog. de France*, vol. xix p. 746 Paris.

1862. Marcou, Jules
Letter to Mr. Joachim Barrande on the Taconic Rocks of Vermont and Canada, Aug. 1862, pp. 1-15, Cambridge, Mass.

1863. Bigsby, J. J.
On the Cambrian and Huronian Formations. *Quar. Jour. Geol. Soc.*, 36–52, Feb. 1863.

1864. Marcou, Jules
Notice sur les gisements des lentilles trilobitifères taconiques de le Poi nte Lévis au Canada. *Bull Soc. géol. de France*, vol. xxi, pp. 236–250 (Paris.)

1865. Logan, W. E.

On the Geology of Eastern New York [Tour with James Hall.] *Canad. Naturalist and Geol.* . Republished, *Amer. Jour. Sci.*, II, xxxix, 96-98.

1860. Perry, J. B.

A point in the Geology of Western Vermont. *Amer. Jour. Sci.* II, xlvii, 341-349 [Important].

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The Marble Border of Western New England. *Middlebury Historical Society*, Vol. 1, Pt. II, 1885.

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On geology at Great Barrington, Mass. *Trans. N. Y. Acad. Sci.* 1887.

1873. Dana, James D.

On the Quartzite. Limestone and associated Rocks of the Vicinity of Great Barrington, Berkshire county, Mass. . *Amer. Jour. Sci.*, III, iv. pp. 362-377; 450-453; v. pp. 47-53; 84-91; vi, pp. 257-278.

1877. Dana, James D.

An Account of the Discoveries in Vermont Geology of the Rev. Augustus Wing. *Amer. Jour. Sci.* III, xii. pp. 332-347; 405-419; xiv, pp. 36-7.

1877. Dana, James D.

On the Relations of the Geology of Vermont to that of Berkshire. *Amer. Jour. Sci.* III., xiv, pp. 37-48; 132-140; 202-207; 257-264.

1878. Prime, Frederick, Jr.

On the Discovery of Lower Silurian Fossils in Limestone associated with Hydromica Slates, and on other Points in the Geology of Lehigh and Northampton counties, Penn. . *Amer. Jour. Sci.* III, xv, 261-269.

1879. Dale, T. Nelson, Jr.

On the Age of the Clay-slate and Grits of Poughkeepsie. *Amer. Jour. Sci.* III, xvii. 57-59.

1879. Dana, J. D.

On the Hudson River Age of the Taconic Schists, and on the dependent Relations of the Dutchess county and Western Conn. Limestone Belts. *Amer. Jour. Sci.* III, xvii, 375-388; xviii, 61-64.

1879. Dwight, W. B.

On some Recent Explorations in the Wappinger Valley Limestone of Dutchess county, N. Y., *Amer. Jour. Sci.* III, xvii, 389-393.

1879. Whitfield, R. P.

Discovery of Specimens of *Maclurea magna* of the Chazy, in the Barnegat Limestone near Newburgh, N. Y., *Amer. Jour. Sci.* III, xviii, 227.

1880. Lesley, J. P.

A Hudson River Fossil Plant in the Roofing Slate that is associated with chlorite Slate and Metamorphic Limestone, in Maryland, adjoining York and Lancaster counties, Pa., *Proc. Amer. Philosoph. Soc.*, xviii, 365; *Amer. Jour. Sci.* III, xix, 71-2.

1880. Ford, S. W.

Note on the Trilobite. *Atops trilineatus* of Emmons [Holding it distinct]. *Amer. Jour. Sci.*, III, xix, 152-3.

1880. Dana, J. D.

List of Papers on the Taconic System [as at first defined by Emmons] [with statements of points]. *Amer. Jour. Sci.*, III, xix, 153-154.

1880. Ford, S. W.

On the Western Limits of the Taconic System. *Amer. Jour. Sci.*, III, xix, 225-226.

1881. Winchell, N. H.

The Potsdam Sandstone. [Discusses Taconic]. *Viiith Ann. Rep. Minn.* pp. 123-136.

1881. Dana, J. D.

Geological Relation of the Limestone Belts of Westchester County, N. Y., *Amer. Jour. Sci.*, III, xxii. 313-315-327-335.

1881. Marcou, J.

Taconic Rocks of the Border of Lake Champlain. *Bull. Soc. géol. France*, Nov., 1880. Noticed *Amer. Jour. Sci.*, III, xxii, 321-2.

1882. Dana, J. D.

Geological Age of the Taconic System. *Quar. Jour. Geol. Soc. Lond.*, xxxviii, 397. Abstract *Amer. Jour. Sci.*, III, xxiv, 291-3.

1883. Hunt, T. S.

The Taconic Question in Geology. *Trans. Roy. Soc. Canada*, Vol. I, Sec. 4. [Dana says "Deficient and one-sided."]

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Notes on the Geology of the Southeastern Portion of the Province of Quebec. *Can. Rep.* for 1880-1-2, A. pp. 6-7.

1883. Walcott, C. D.
The Cambrian System in the United States and Canada, *Bull. Philosoph. Soc.*, Washington, vol. vi, pp. 98-102.

1884. Walcott. C. D.
On the Cambrian Fauna of North America. *Bull. U. S. Geol. Surv.*, No. 10, pp. 55 and nine plates.

1884. Winchell, N. H.
[Incidental discussion of Taconic in] The Crystalline Rocks of the Northwest. *Proc. Amer. Assoc.*, 1884, pp. 363-379.

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1884. Dana, J. D.
On the Southward Ending of a Great Synclinal in the Taconic Range. (Read before the British Association). *Amer. Jour. Sci.* III, xxviii, 268-275.

1884. Hall, James.
On the Hudson River Age of the Taconic Slates. [Notice of by Dana]. *Amer. Jour. Sci.*, III, xxviii, 311-312.

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The "Taconic system," and its Position in Stratigraphic Geology. *Proc. Amer. Acad. of Arts and Sciences*, Vol. xii, 174-256. [With bibliographical statements and letters from Emmons and Barrande.]

1885-7. Dana, J. D.
On Taconic Rocks and Stratigraphy, with a Geological map of the Taconic region. *Amer. Jour. Sci.* III, xxix, 205-222; 437-443; xxxiii, 270-276; 393-412.

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On Lower Silurian Fossils from a Limestone of the original Taconic of Emmons. [Amer. Assoc., 1885], *Amer. Jour. Sci.* III, xxxi, 241-248.

1886. Ford. S. W. and W. B. Dwight.
Preliminary report upon Fossils obtained in 1885, from metamorphic limestones, of the Taconic series of Emmons, at Canaan, N. Y., *Amer. Jour. Sci.* III, xxxi, 248-255, with plate vii.

1886. Dana, J. D.
The History of Taconic investigation previous to the work of Professor Emmons, (Address, Berkshire Historical Soc., Feb. 1885.) *Amer. Jour. Sci.* III, xxxi 399-401.

1886. Walcott, C. D.
Classification of the Cambrian system of North America (Read before National Academy of Science, Washington, Apr. 23, 1886) *Amer. Jour. Sci.* III, xxxii, 138-157.

1886. Walcott, C. D.
Second Contribution to the Cambrian Faunas of North America, 369 pp. 8vo. with 33 plates. *Bull.* No. 30. *U. S. Geol. Surv.*

1886. Hunt, T. S.
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1887. Winchell, N. H.
Notes on Classification and Nomenclature for the American Committee of the International Geological Congress. *American Naturalist*, March, 1887, p 693-700.

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The Taconic Question Restated. *Amer. Naturalist*. xxi, 114-125; 238-250; 312-320.

1887. Dwight, W. B.
Palæontological Observations on the Taconic Limestone of Canaan, Columbia county, N. Y. (Amer. Assoc. Aug., 1886,) *Amer. Naturalist*, 1887, p. 270.

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Geologic Age of the Lowest Formations of Emmons' Taconic System. Read before Philosophical Soc. Washington, Jan. 15, 1887. Abstract, *Amer. Jour. Sci.*, III, xxxiii, 153-4.

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The Views of Professor Emmons on the Taconic Question. *Amer. Jour. Sci.*, III, xxxiii, 412-419.

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Fauna of the "Upper Taconic" of Emmons, in Washington county, N. Y., *Amer. Jour. Sci.*, III, xxxiv, 187-199.

1887. Irving, R. D.
Is there a Huronian Group? *Amer. Jour. Sci.*, III, xxxiv, 204-216; 246-263; 365-374.

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Notes on the part of the Huronian Series, in the neighborhood of Sudbury Canada. *Quar. Jour. Geol. Soc.* London, Feb. 1888, pp. 32-35.

1888. Marcou, Jules.
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Some Objections to the Term Taconic Considered. *Amer. Geologist*, i, 162-172, March.

1888. Winchell, N. H.
Note in Reply to Walcott. *Amer. Geologist*, i, 220-224.

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The Taconic System as established by Emmons, and the Laws of Nomenclature applicable to the Subject. *Amer. Geol.* i, 235-245.

1888. Winchell, Alexander.
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Palæontologic and Stratigraphic "Principles" of the Adversaries of the Taconic. *Amer Geologist*, ii, 10-23; 67-88, July and Aug.

1888. Selwyn, A. R. C.
Huronian, Taconic and Quebec. *Amer. Geologist*, ii, 61-62, 135.

1888. Winchell, N. H.
[Use of the term Taconic, in Report to International Committee] *Amer. Geologist*, ii, 208-211.

1888. Walcott, C. D.
On the Taconic System of Emmons [Compiled as an expression of opinion] *Amer. Geologist*, ii, 215-219, with Note by N. H. Winchell, 220-224.

1888. Vogdes, A. W.
Some Forgotten Taconic Literature. *Amer. Geologist*, ii, 352-355.

1888. Walcott, Charles D.
The Taconic System of Emmons, and the Name Taconic in Geologic Nomenclature. *Amer Jour. Sci.* III, xxxv, 229-242; 307-327; 394-401.

1888. Dana, James D.
A brief History of Taconic Ideas. *Amer. Jour. Sci.* III, xxxvi, 410-427.

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Barrande and the Taconic System. *Amer. Geologist*, iii, 118-137.

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The Taconic in the Salt Range of the Punjab (India). *Amer. Geologist*, iv, 60-62.

1889. Howley, James P.
The Taconic of Eastern New Foundland. *Amer. Geologist*, iv, 121-125.

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Stratigraphical position of the *Olenellus* Fauna in North America and Europe. *Amer. Jour. Sci.*, III, xxxvii, 374-392; xxxviii, 29-42.

1889. Dwight, W. B.
Recent Explorations in the Wappinger Valley Limestone, No. 7. In the Millerton-Fishkill Limestone Belt; also in a Belt near Rhinebeck. *Amer. Jour. Sci.*, III, xxxviii, 139-153.

1890. Dwight, W. B.
Fossils of the western Taconic Limestone, in the eastern part of Dutchess county, N. Y. (Announcement.) *Amer. Jour. Sci.*, III, xxxix, 71.

DOUGLASS HOUGHTON.

1831. Dr. Houghton's earliest record in respect to the rocks of Michigan is found in his report to the Secretary of War as Botanist of Schoolcraft's Expedition.* Speaking of the copper of lake Superior, he says: "After having duly considered the facts which are here presented, I would not hesitate to offer as an opinion that the trap rock formation was the original source of the masses of copper which have been observed in the country bordering on Lake Superior; and that at the present day, examinations for the ores of copper could not be made in that country with hopes of success, except in the trap rock itself; which rock is not certainly known to exist in any place upon lake Superior other than Kewena point." This opinion on the source of the native copper he had subsequently abundant opportunity to confirm, though opposed by much scientific incredulity.

1840. In his Third Annual Report on the geology of Michigan, dated February 3, 1840, summarizing observations of 1839, Dr. Houghton treats of the "Upper Peninsula." Under the head of "General Geology of the South and Southeasterly Part of the Upper Peninsula," † after describing the distribution of the "Primary rocks" in Michigan, he says: "The immense Primary region of which the line described may be considered as it were, a single point, stretches nearly continuously, many hundred miles northwesterly, skirting a portion of the shores of lake Superior, and in conjunction with the trap rocks, constituting the highlands between that lake and lake of the Woods. From these highlands it stretches a little east of lake Winnipeg, far to the northwest, finally constituting the immense "barren grounds" of the British Possessions. It is also well known that this range of primary rocks stretches in an easterly direction through the interior of the upper province of Canada" (p. 11).

This is the earliest general location of the eastern nucleus of the continent.

1890. Marcou, J.
The Lower and Middle Taconic of Europe and North America. *Amer. Geologist*, v, 357-375; vi, 78-102, 222-233.

1890. Winchell, N. H. and H. V. Winchell.
The Taconic Ores of Minnesota and Western New England. Read before the Geological Society of America, Aug. 19. *Amer. Geol.* Nov. 1890.

1890. Winchell, N. H.
What Constitutes the Taconic Mountains? Read before Sec. E, Amer. Assoc. Adv. Sci., Aug. 22, 1890. *Amer. Geol.*, vi, 247.

*Nov. 14, 1831. Also Henry R. Schoolcraft, *Discovery of the Source of the Mississippi* New York, 1834, pp. 287-292.

† *Senate Document* No. 8, 1840, p. 10.

Some further but disconnected quotations will be introduced.

"On the mainland at these 'narrows' [the place where the current of Ste. Marie's river meets the slack-water of lake Huron] and extending for several miles, the knobs are composed of compact greenstone, occasionally partaking of a sub-slaty character, and under which circumstances, the rock bears a close analogy to some of the varieties of primary argillite."

"On the northern part of the island of St. Joseph, a fraction of the southeastern part of Sugar island, and a portion of the main land on the east, the place of the hornblende rock is supplied by granular quartz rock, usually white, but sometimes passing to a reddish or deep red color."

"In the range of hills bounding the easterly side of Great Lake George, talcose slate was observed, but to what extent it exists I am unable to say" (p. 13).*

It appears that Dr. Houghton's conception of "Primary rocks" was rather broad. The granular quartz rock mentioned is now known to be a westward extension of the "Huronian" quartzites of the Thessalon valley in Canada. The "talcose slate" on the other hand, probably belongs to the Marquette iron-bearing series which by the present writer has been suggested to be an older system than the Huronian. It is worthy of note also, that Dr. Houghton reports the "Lake Superior sandstone" as resting "against and upon the Primary range of the Ste. Marie's river." That is, at one point the "talcose slates" (Marquette series) rest in contact with the gneisses; at another, the overlying quartzyte (Huronian) extends over to the gneiss; and at another, the still higher sandstone (Palæozoic) reaches over to the gneiss. Thus, it is unsafe to conclude that the formation resting on the gneiss at any particular spot is the one historically next in order of age.

1841. In his report for the following year, †he continues his description of the Northern Peninsula. His conception of Primary rocks appears more restricted, for he says they "are chiefly granite, syenite and syenite granites." (p. 15.) After describing the vast development of "Trap Rocks," he recognizes a group designated "Metamorphic Rocks." "Flanking the Primary rocks on the south," he says, "is a series of stratified rocks consisting of talcose, mica

* In view of the recent extensive employment of "field stones" in some parts of the state, in the walls of substantial structures, the following quotation from this report possesses interest: "In the immediate vicinity of the surveyed line of the Ste. Marie's canal, transported masses of granite, hornblende, sienite and quartz rocks abound, and they may be economically employed for the construction of the proposed locks, and will make an enduring structure." (p. 15).

†Senate Document No. 16, 1841.

and clay slates, slaty hornblende rock and quartz rock; the latter rock constituting by far the largest proportion of the whole group." These represent the group of rocks in the Menominee region, which Dr. Emmons so eagerly accepted as representatives of the Taconic system in Michigan.

The following is an interesting early notice of the mode of occurrence of serpentine. "In traversing the country southeasterly from Little Presqu' ile, the point referred to as the most southeasterly prolongation of the granite, this last rock passes almost insensibly into a serpentine rock* which has a regular jointed structure, sometimes approaching to stratification; continuing in the same direction, we find a series of hornblende slates, talcose, mica and clay slates, resting against the serpentine rocks; and still farther to the southeast, the rock becomes almost uniformly quartz. The rocks of this group dip irregularly to the south and southeast, while the cleavage of the slate is very uniformly to the north," (p. 17.)

A gradual passage from granite to "greenstone" is noted as follows: "As we proceed northwesterly from the southeast boundary of the Primary, over the several broken ranges of hills, we find the character of the rocks in mass almost imperceptibly changing. The quartz as a mineral gradually forms a less important part, and it finally almost wholly disappears, leaving a binary compound of feldspar and hornblende, which then assumes a granular structure, constituting greenstone. The intermediate rock between the syenite and greenstone ranges may not inappropriately be called a syenitic greenstone," (p. 23.)

The granitic rocks are intersected by dikes which can be traced continuously and with increasing abundance, into the greenstone masses, showing the granitic ranges to be the oldest (p. 24).

In reference to amygdaloids he says: "I am disposed to refer the origin of much of the amygdaloid rock to the fusion of the lower portion of the sedimentary rocks referred to, for the reason that as we pass south from the junction [receding from the sedimentary rocks] the amygdaloid rocks wholly disappear, their places being supplied by greenstone; and again, so intimately are they blended that it is frequently impossible to determine where the amygdaloid ceases and the upper sedimentary rocks commence. Fragments of the sedimentary rocks, the characters of which can be clearly recognized, are not of rare occurrence, imbedded in the amygdaloid rock, a circumstance which, although by no

*The curious history of opinion concerning this much discussed rock is compiled by Dr. Wadsworth in *Bull. Mus. Comp. Zool.*, Geol. Series, I. pp. 60-65.

means conclusive, should not be overlooked in considering the subject" (pp. 27 and 28).

Of the conglomerate rock he says: "It may without doubt be considered as a trap tuff, which was gradually deposited or accumulated around the several conical knobs of trap during their gradual elevation" (p. 33). It is very variable in thickness. There is "scarcely a pebble of any other rock than trap." They are cemented by "a mixed calcareous and argillaceous cement more or less colored by iron, and exceedingly firm. The conglomerate is "imperfectly stratified in masses of immense thickness," in its maximum a little east of Montreal river, estimated at 5,260 feet, (pp. 34, 35).

The formation described as "mixed conglomerate and sandrock" "is made up of an alternating series of conglomerate and red sandstones which rest conformably on the conglomerate rock last described" and "in strictness should probably be considered as a member of the conglomerate itself" (p. 18). Its greatest observed thickness is 4,200 feet. The conglomerate beds resemble in all respects the underlying conglomerate, and the intervening sandstone beds are composed of the same materials, but are sometimes ripple marked, and were thus evidently deposited in shallow water. These sandstone beds are very distinct in composition from the "red" and "grey" sandstones higher in the series" (pp. 19, 37).*

It will serve to convey an idea of the extent of Dr. Houghton's researches in the Upper Peninsula to state that the *Exec., Doc.*, 1849-50, Part III, contains (p. 880), the following among Hough-

*The "red sandrock" associated with "shales" is much more quartzose than the beds intercalated with the conglomerate. It attains a maximum thickness of 6,500 feet. "On the southeast side of Keweenaw bay, near its head, an argillaceous rock appears" "evidently embraced in, or rather may be said to constitute a member of, the sandstone series." It is sometimes, "in the form of a slate," though usually it "closely resembles indurated clay." It can be cut with the knife, and the Indians have long used it as a pipestone. A similar rock appears at several other points in the interior. These slates are shown by his notes of 1845. to pass under the sandstone.] The "Upper, or Grey Sandrock" is no part of the Lake Superior sandstone. While the latter dips northeasterly. this dips southeasterly, and is conformable with the overlying limestones. The "Grey Sandrock" forms a range of hills extending westward from Pt. Iroquois to the Pictured Rocks, where they abut upon the shore of the lake. It is Dr. Houghton's opinion, therefore, that the Pictured Rocks are a higher formation than the Red Sandstone, generally contemplated as the "Lake Superior Sandstone" (19,42.) The Lake Superior sandstone Dr. Houghton was at first inclined to parallelize with the "Old Red Sandstone" (*Report*, 1838); but, in a paper read before the Association of American Geologists in 1843, he assumed it as identical with the "New Red Sandstone" (*Amer. Jour. Sci.*, xlv, 160.) Later he synchronized it with the Potsdam sandstone of New York, and this view was embodied in his notes of 1845 (*The Mineral Region of Lake Superior*, 1846, by Jacob Houghton.) The statement is contained in a report by Bela Hubbard—page 118—compiled from Dr. Houghton's notes;) Also. *Executive Docs.*. 1849-50, pt. III. p. 839. The same was noted on the plats of 1845. See also the testimony of Foster and Whitney, *Report on the Geology of the Lake Sup. Land Dist.*, Pt. II, p. 138, and *Proc. Amer. Assoc. Adv. Sci.* May, 1851, p. 23.

ton's results: 1. "A Geological Map of the Townships of the Northern Peninsula of Michigan subdivided by D. Houghton, D. S. in the year 1845." (This covers Keweenaw Point.) 2. "Geological Map of Township Lines in the Northern Peninsula of Michigan, surveyed by Wm. A. Burt, D. S. in the year 1845, for D. Houghton, under said Houghton's contract for surveys with reference to Mines and Minerals" (The region on Little Bay de Noquet and along the Escanaba river and to lake Superior.) 3. "Geological Map of a District of Township Lines in the Northern Peninsula of Michigan, surveyed by Wm. A. Burt in the year 1846." (Region between the Escanaba and Menominee rivers.) Also (p. 896.) 1. "Geological Map of a District east and west of the Ontonagon, subdivided by Messrs. Higgins and Hubbard under a Contract bearing date April 23, 1846" (From Portage lake to Carp river.) 2. "Geological Map of the District subdivided by Messrs. Hubbard and Ives, under Contract bearing date September 7, 1846." (The Region from Presqu' ile to L' Anse.) These six maps were produced under the system of combined linear and geological surveys inaugurated by Dr. Houghton. Thus nearly the whole of the Upper Peninsula had been geologically mapped before the signing of the contract with Foster and Whitney, and without including the results of Dr. Jackson's survey. Mr. Hubbard gives also, five handsomely drawn sections from lake Superior, across the country southward, besides five lithographed views.

The following is Dr. Houghton's latest view of the succession of rocks in the Upper Peninsula of Michigan:

6. Upper or Gray Sandstone (Houghton, 1841, pp. 19, 41) not conformable with next below.

5. Lower or Red Sandstone and Shales (Houghton, 1841, pp. 18, 37). Identified with Potsdam Sandstone.

4. Mixed Conglomerate and sandstone (Houghton, 1841, pp. 18, 35).

3. Conglomerate (Houghton, 1841, pp. 17, 33).

2. Metamorphic rocks (Houghton, 1841, pp. 16, 31). Quartzite, Argillite, Talcose and Clay slates, Mica slate.

1. Primary rocks (Houghton, 1841, pp. 15, 23). Granite, Gneiss, Syenite and Syenitic Granite.

Numbers 6 and 5 are probably both representatives of the New York Potsdam. Numbers 4 and 3 are the Keweenawan System of Chamberlin and Irving, and number 2 occupies the place of the Taconic system of Emmons.

EDWARD HITCHCOCK.

1833. In his Final Report on the Geology of Massachusetts,* Professor Edward Hitchcock enumerates, among others, the following rocks or groups of rocks mineralogically considered: Graywacke, Argillaceous slate, Limestone, Scapolite rock, Quartz rock, Mica slate, Talcose slate, Serpentine, Hornblende slate, Gneiss — all which are stratified; Greenstone, Porphyry, Syenite and Granite — which are unstratified. Of the Berkshire limestone, he thinks a part is "primitive, in the Wernerian acceptation of the term, for it is interstratified with gneiss and mica slate" (p. 297). But the mica slate in its westward extension becomes clay slate, and the limestone less crystalline. Passing into New York, the limestone assumes the character of Dewey's "transition limestone."

"But a singular anomaly in the superposition of the series of rocks above described presents a great difficulty in the case. The strata of these rocks almost uniformly dip to the east; that is, the newer rocks seem to crop out beneath the older ones, so that the saccharine limestone associated with the gneiss in the eastern part of the range seems to occupy the uppermost place in the series. Now, as superposition is of more value in determining the relative ages of rocks than mineral characters, must we not conclude that the rocks as we go westerly from Hoosac mountain, do in fact, belong to older groups? The petrifactions which some of them contain, and their decidedly fragmentary [fragmental] character will not allow such a supposition to be indulged in for a moment. It is impossible for a geologist to mistake the evidence which he sees at almost every step, that he is passing from older formations, just as soon as he begins to cross the valley of Berkshire towards the west. We are driven then, to the alternative of supposing either that there must be a deception in the apparent outcrop of the newer rocks from beneath the older, or that the whole series of strata has been actually thrown over, so as to bring the newest rocks at the bottom. The latter supposition is so improbable that I cannot at present admit it" (pp. 297-298). He then supposes two unconformities to have been produced — one at the west base of Hoosac mountain between the gneiss and the quartz rock, and the other farther west, in the valley of Berkshire. He names some difficulties involved in the acceptance of such an explanation, but feels compelled to adopt it provisionally. Moreover, he says, "I am sustained in this opinion by that of Dr. Emmons of Williams College, whose acuteness of observation and accuracy of discrimina-

* Report on the Geology, Mineralogy and Botany and Zoology of Massachusetts. By Edward Hitchcock. Amherst, 1833, Roy. 8-vo, pp. 700.

tion in the various departments of natural history are well known" (p. 300.

Professor Hitchcock frequently touches on questions of metamorphism. In his "Theoretical Considerations" on mica slate, after explaining the strict Wernerian view of the aqueous origin of all the primary rocks, and pointing out the improbability that so many different substances should crystallize out simultaneously from the same solution, he says:

"I am inclined therefore, to the theory which supposes that they were originally mechanically deposited from water, like the existing secondary and tertiary rocks, and that they have subsequently been subjected to such a degree of heat as enabled their materials to enter into a crystalline arrangement, without destroying their structure" (p. 350).

In reference to serpentine, professor Hitchcock advances some suggestions which were singularly in advance of his time. He speaks of prevailing divergences of opinion as to its nature and origin, and decides to describe it in connection with stratified rocks, though he finds it occurring unstratified as well as stratified. He mentions the various circumstances of its occurrence and adds:

"In all cases (except perhaps that at Newport) our serpentines are associated with talc, either pure and foliated, or as steatite, or chlorite slate, or talc and quartz. The two minerals (talc and serpentine) are intimately blended together, and pass into one another by insensible gradations, and in all the cases described by the writers above referred to, talc was present. Is it not natural then, to suspect that serpentine is talc, or talc serpentine, altered by heat? And since the talc is schistose, and the serpentine massive, the latter must have been produced from the former. . . . It may be found that serpentine has been produced from various rocks which contained the necessary ingredients. But that heat has been employed in its production, cannot, it seems to me, be reasonably doubted" (pp. 372, 373).

In some "theoretical considerations" concerning gneiss, he says:

"Since gneiss is composed of the same simple minerals as granite, it is natural to infer that both must have had a similar origin. And especially are we led to such a conclusion, when we see in granitic gneiss a gradual passage from the one rock to the other. That granite has resulted from heat instead of aqueous deposition seems to me to be so well established that the opinion that imputes to it such an origin ought no longer to be regarded as hypothesis, but as legitimate theory. . . . At present I shall assume that theory to be the correct one which supposes granite to have result-

ed from the melting down of other rocks; the fused mass having cooled so slowly as to present a confused crystallization. It is at least, a probable supposition, that the rock out of which it was produced was of mechanical origin, and consequently stratified. Now, if the central heat was not sufficient entirely to melt this stratified rock, yet it would be powerfully affected a considerable distance upward from the molten mass. The first in immediate contact with the melted portion would be partially fused, and hence give origin to granitic gneiss. Another portion might be converted into porphyritic gneiss; another, into lamellar; another into schistose, etc. All the rock, we may suppose so near the fluid granite, and so long in contact with it, before cooling, that crystalline would succeed to a mechanical arrangement of all its ingredients, without losing the stratified disposition (p. 400).

In discussing the history of granite, professor Hitchcock states that he infers its igneous origin "from the inclined position of the older stratified rocks; from the manner in which it is intruded among the stratified rocks; from the mechanical effects which it appears to have exerted upon the stratified rocks in its immediate vicinity; from its chemical effects upon the surrounding strata, and from its crystalline structure, and the numerous crystallizations of other substances that have taken place in it" (pp. 509-515).

1840-1. The inversion of the strata of the Appalachian system is referred to again in his Elementary Geology.* Speaking of overturned strata in the Alps, he says:

"I have no small reason to believe that a similar folding and overturning of the strata have taken place on a vast scale in the United States. Along the western part of the Green and Hoosac mountains in New England, occur interstratified beds of gneiss, mica slate, talcose slate, clay slate, limestone and older Silurian rocks which are either perpendicular or have a high easterly dip; and yet the oldest members of the series are found along the eastern side of this belt, and the strata become newer and newer as we go westerly; that is, the oldest rocks lie apparently over the newer ones. These appearances present themselves nearly the whole distance from Connecticut river to Hudson river—a breadth of nearly fifty miles." He then describes the folding, overturn and denudation which would result in the present structure and surface aspects. "It appears further, from the Geological Reports of Professors Mather on New York, Henry D. Rogers on New Jersey and Pennsylvania, William B. Rogers on Virginia, and Troost on Tennessee, that these same

**Elementary Geology.* The Preface to the first edition is dated August 1, 1840; that of the third edition, April, 1842. I quote from the third, 12mo., pp. xii 352.

rocks with similar inversion of their dip, occur in all those states, forming a considerable part of the Appalachian mountains; and that in fact, they extend almost uninterruptedly from Canada to Alabama—a distance of nearly 1200 miles; and if the above theory of the folding and inversion of this belt of rocks be correct in the latitude of Massachusetts, it is without doubt, true over this vast extent of country."*

The subject of inverted arrangement of the Appalachian strata was under careful consideration at this time, by the brothers Rogers, as well as by Dr. Hitchcock. The earliest enunciation of the conception of an inverted fold had been made by Dr. Hitchcock in 1833. His conception however, was not identical with that of the brothers Rogers. He spoke only of a single anticlinal, while the Rogers brothers saw a succession of anticlinals all tilted westward across the main mass of the Appalachians. In an address delivered in 1841, he said:†

"There is no small reason to believe, indeed, that on the western side of the continent, from Cape Horn, to the northern Arctic Ocean, *one vast anticlinal axis exists*, along the crest of the Andes and the Rocky mountains. Subordinate and perhaps intersecting systems of strata will undoubtedly be found along the extended line, but this appears to be the grand controlling, and probably the most recent, uplift of the continent. . . . The Appalachian range of mountains forms *another anticlinal ridge*, extending northeasterly through New England, and not improbably to Labrador" (pp. 264-265).

In the Elementary Geology before quoted, Dr. Hitchcock amplifies his defense of the metamorphic theory then recently introduced into geology by Alexander Brongniart. The main points stated are briefly these: 1. It shows why, amid so much evidence of chemical agency in the formation of the primary rocks, there is still so much proof of the operation of mechanical agencies. 2. It shows why silicates predominated in the earlier periods of the globe, and why limestone and carbon were more abundant at the later periods. 3. It explains the absence of organic remains in the primary stratified rocks. 4. It explains, too, the reason why carbon is much less abundant in the older than in the newer rocks. 5. It explains the imperceptible graduation of gneiss into granite" (pp. 259-61).

***Elementary Geology*, pp. 36, 37. The subject is also taken up in his Anniversary Address (cited below,) p. 268.

†First Anniversary Address Before the Association of American Geologists at their Second Annual Meeting in Philadelphia, April 5, 1841. *Amer. Jour. Sci.*, vol. xli, pp. 232-275.

In the Anniversary Address from which I have quoted, Dr. Hitchcock considers briefly the origin of dolomytes:

"As to that portion of this field [of dolomite and dolomitic limestones] which has fallen under my observation, I find that with one or two unimportant exceptions, all the cases of dolomitized limestone occur either in the vicinity of a fault or of unstratified rocks, or of the oldest gneiss. The pure dolomite is usually found where there is reason to believe extensive dislocations of the strata occur; and the marks of stratification in the limestone disappear nearly in proportion to the amount of magnesia which it contains, so that the pure dolomite shows scarcely any traces of it. I doubt not that similar conclusions will follow an examination of other parts of this deposit, so remarkably uniform in the geology of this continent; — and moreover, these conclusions correspond to the history of dolomitization in Europe. They seem to render probable the theory of sublimation from the interior of the earth."*

1859. In the Final Report of the Geology of Vermont,† Dr. Hitchcock, who assumed the responsibility, as he tells us, though most of the field work was done by others, takes up early in the report, the subject of "The Metamorphism of Rocks" (p. 22). In the following language he sets forth his general conception of the *modus operandi* of hypogeal metamorphism.

"If the globe was once in a molten state, the crust which first formed over its surface must have been some kind of unstratified rock. When it became coal enough to allow water to condense on the surface and form oceans, the waves would wear away portions of the rock, and deposit the fragments in the form of gravel, sand and clays. These by the action of internal heat might be hardened, and become conglomerates, sandstones and shales. If new beds of materials should be thrown upon these strata it would cause the internal heat to penetrate further upward into the conglomerates, sandstones and shales, and, by the help of water, render the rocks plastic and convert them from mechanical into crystalline rocks, without destroying the planes of stratification, though generally obliterating all traces of organic structures which they might have contained, and changing the laminated structure into foliation and cleavage. After all this, water may have acted mechanically on these strata, wearing them away, and forming other deposits of puddingstones, sandstones and shales. Meanwhile also, the inter-

*Amer. Jour. Sci., xli. 240.

†*Report on the Geology of Vermont, Descriptive, Theoretical, Economical and Scenographical.* By Edward Hitchcock, Edward Hitchcock, Jr., Albert D. Hager, Charles H. Hitchcock. 2 vols. 4to. Claremont, N. H., 1861. The preface is written by Dr. E. Hitchcock, and dated Oct. 1, 1859, and Oct. 2, 1860.

nal heat working farther upward, as it certainly would by the accumulation of new beds of detritus, might melt over the lower beds of the strata, converting them into unstratified rock. And thus might the same materials have been subject to repeated and most thorough metamorphosis" (p. 22).

The writer then proceeds to an account of the "agents of metamorphism," heat and water, recalling the well known results of experiments and reasoning, and treats with considerable detail the evidences of "a former plastic condition of the rocks". He cites numerous observations, showing that rocks and rock-constituents must have been reduced to a plastic or semi-plastic condition, subsequent to their original consolidation, and so continued for a great length of time", In this connection he cites numerous instances of pebbles which have been elongated and flattened—some even at length being "converted into the silicious folia of schists, and the cement into mica, talc and feldspar". He refers to the pebbles near Newport, Rhode Island; others at intervals along the western side of the Green mountains, and especially a locality in Plymouth, Vermont, where pebbles occur under such forms as to indicate a state of plasticity. In Wallingford the beds of conglomerate thus altered alternate with beds of talcose and mica schist (pp. 28–38, 476). Some of the facts point toward the inference that schists and gneisses even may have originated from the extreme flattening and elongation of the pebbles of an original conglomerate, though as a fact, pebbles had not at that date been found actually occurring in gneiss. Dr. Hitchcock expects that such views would "be pronounced preposterous by able geologists*". In a syenitic rock, however, found in Vermont and Massachusetts, undoubted pebbles had been observed. Other facts have been noted by the writer: See, Conglomerates enclosed in Gneissic Terranes, *Amer. Geologist*, iii. 153-165; 256-261; *Sixteenth Ann. Rep.*, Minn. pp. 218-222, 334. He says:

"We define this rock as a conglomerate with a cement of syenite or granite, or as a syenite or granite with pebbles in it, sometimes thickly and sometimes sparsely disseminated". . . . "These facts certainly give great plausibility to the view which supposes granite and syenite to be often the result of the metamorphosis of stratified rocks" (pp. 40, 41; ii, 565, 566.*)

In connection with the discussion of metamorphism the writer

*Dr. Hitchcock's expectation has found fulfillment in the dissent recorded by Dr. M. E. Wadsworth *Bull. Mus. Comp. Zool.*, Geolog. Series, i; B. S. Lyman, *Proc. Amer. Assoc. Adv. Sci. 1866, p. 83.*

*See W. B. Rogers' views in opposition to those of Hitchcock stated in *Proc. Bos. Soc. Nat. Hist.* 1861 and *Amer. Jour. Sci.*, II, xxxi, 440-442, May, 1861.

reminds us of an inference which is too obvious to have fallen into such general forgetfulness. He says:

"Metamorphism shows us that the earliest formed rocks on the globe may have all disappeared. None of the first formed crust may remain. Or, if any of it is left, it would be impossible to distinguish it from subsequent formations. So that the idea of a primary granite or any other rock, in the strict sense of the term, has no foundation in nature" (p. 47.)

In close connection with this subject, we cite some passages from another chapter, touching the nature of foliation. Speaking of the gneissic rocks of Vermont, he says: "In certain districts the strata are exceedingly contorted, and the average dip and strike are the ones that we recorded. There is not a square mile of this rock in the State where there are not more or less of these irregularities. In a few instances, the difficulty of ascertaining the true position is so great that we have not attempted it."

After illustrating a striking particular instance of these contortions, he concludes:

"This state of things suggests two important topics: *First*, Do not these contortions prove that the layers that have suffered this twisting are the strata, and not the bedding of cleavage or foliation? For the beds between cleavage planes are rarely contorted. The strata may be contorted while the cleavage planes cross them with perfect regularity. In fact, the cleavage does not appear to have been produced until the strata had been quietly settled into their present positions, as a general thing." The *second* topic relates to the effect of contortion on calculation of thickness of terranes*.

Speaking of the position of the "red sandrock" of northern Vermont," regarded by Emmons as belonging to the age of the Potsdam and Calciferous, Dr. Hitchcock says:

"Without an exception, it rests upon the Hudson River group. The stratigraphical evidence goes to show that the red sandrock is of the age of the Medina sandstone or Oneida conglomerate. This was the original view of Dr. Emmons, and has since been sustained by Professors C. B. Adams, W. B. Rogers† and W. E. Logan. It is certainly an objection to this view that the characteristic fucoid, *Arthrophycus Harlani*, of the Medina sandstone

*Geology of Vermont, p. 518.

†A communication is cited from W. B. Rogers, which is said to have been prepared for the *Amer. Assoc.* at Albany in 1851, but not published, in which this view is argued (*Geol. Vt.*, p. 326.) This view of Dr. Hitchcock, he states later in his Report, (p. 435) "has now been changed."

has never been found in it." (p. 340.) Compare A. D. Hager's description of "Red Sandrock mountains," (ii, 875.)

In reference to the "Quartz rock" of the older geologists—the "Granular quartz," of Emmons, the "Potsdam sandstone" of the brothers Rogers, of Hall and later geologists, Dr. Hitchcock presents no facts decisive of the question of its position. As to the "Georgia slate"—the "Black slate" and "Taconic slate" of Emmons—the "Hudson River group" of Hall—the "upper part of the Hudson River group, or a distinct group above the Hudson River group" on the authority of Sir William Logan—a "primordial" terrane, as determined by Barrande—Dr. Hitchcock has no decisive facts to offer. He recites the principal data touching the lithological and stratigraphic characters of the group, and acquiesces in the verdict then recently rendered by Hall and Logan in reference to the geologic age, expressly disagreeing with Emmons in regard to any unconformity between the "Georgia slates" and the "red sandrock."

The "Stockbridge limestone" of Emmons, Adams and Thompson is christened "Eolian limestone" (from Mt. Eolus, or Dorset mountain). This is the "Granular limestone" of Dewey, and "metamorphic Trenton limestone" of Rogers, Logan and Hunt. The "Sparry limestone" of Emmons is included in it. As to their geological position, Dr. Hitchcock says: "We incline to the opinion that they must probably be placed as high as that [the Corniferous] formation, or as low as the Lower Silurian, to which last position Mr. T. S. Hunt assigns them. Either position abounds with difficulties, and we are hardly prepared to choose between them," (p. 421). He has changed his view in reference to dolomitization. He says:

"The old notions that it has been done by igneous fusion, or by the sublimation of carbonate of magnesia do not all satisfy the facts as we now understand them," (p. 424). He then quotes from Bischof to the effect that dolomytes can only be regarded as a product of the alteration of limestone in the wet way (p. 424).

The "Magnesian slate" of Dr. Emmons, and of Adams and Thompson, is described by Dr. Hitchcock under "Talcoid schists," because analysis shows that they are essentially aluminous (p. 425). He regards them as probably newer than the Eolian limestone (p. 433).

The theory of the metamorphic origin of granites gains strength in the mind of the author, and he returns to it with new thoughts and new supports. He points out the improbable assumptions of

the theory of molten granitic protrusions, save in an exceptional way, (ii. pp. 572, 573), and enforces the arguments for aqueo-igneous fusion of pre-existing rocks as the most probable origin of granites (ii., 574–6). He maintains, 1. The accepted theory of igneo-aqueous softening for recognized schistose rocks needs only an extension in the same direction, to apply to granitic rocks. 2. The order of solidification of the constituents of granite has not been that which would have been followed in a case of cooling from a state of fusion. 3. The existence of hydrated simple minerals, or of such as must have been formed in the wet way, or of such as would undergo partial or entire decomposition, even at a red heat, is an evidence favoring the igneo-aqueous theory. 4. The character of thin tortuous granitic veins, instead of evincing molten fluidity, seems more probably to have resulted from a state of solution or softening in alkaline thermal waters.

Dr. Hitchcock never made an explicit record of his views in reference to the tenability of the Taconic system as a whole. He opposed the earlier views of Emmons in reference to a non-inversion of the strata in western Massachusetts—though at one time wavering on that subject—and is commonly ranked with the brothers Rogers as an opponent of Emmons' claims. But Hitchcock's conception of the assumed overturn was different from that of the brothers Rogers; and Emmons yielded at last, to the evidence of a *folded* overturn. In reference to the position of the "red sandrock" at Highgate and elsewhere, Hitchcock in the earlier portion of his Vermont report, deferred to the positive opinion of W. B. Rogers*, and in this respect was again at variance with Emmons, who held it to lie in the position of the Potsdam sandstone and the Calciferous sandrock†. As to the Georgia slates, which the majority of American geologists had pronounced equivalents of the Hudson River series, or newer, Dr. Hitchcock appears finally to waver. He quotes the changed opinions of Logan, and the positive assertions of Barrande, as well as Hall's explanations of his positions, and as to himself, confesses that he no longer takes sides—though apparently he admits, with Logan, that the Point Lévis rocks are subordinate to the Potsdam, instead of near the middle Silurian. But on still later pages‡, he compiles a resume of the Taconic system, saying, "We shall use the terms which are employed by Prof. Emmons, and shall endeavor to represent his ideas *as they are published*, as faithfully as though we were the amanuensis of an

**Proc. Amer. Assoc.*, Albany, 1851.

†*American Geology*, vol. 1, pt. ii., pp. 88, 128, 1855.

‡*Vermont Report*, pp. 434-447.

advocate of the Taconic system." This epitome, therefore, is not compiled in a controversial spirit. Moreover, it soon becomes manifest that some of the reasoning is Dr. Hitchcock's own; that is, he assumes the character of a friend and advocate. He concludes with a statement of "presumptions in favor of the Taconic system": "1. Its similarity to the Cambrian system in Europe." From this is deduced, "2. A presumption that the old doctrine of the Laurentian age of the New England azoic rocks is correct." "3. The Taconic rocks are physically unlike the Lower Silurian." "4, The Taconic system underlies the Lower Silurian." "5. The thicknesses of the Taconic and Lower Silurian rocks do not agree." "6. The organic remains of the Taconic and Lower Silurian rocks are entirely different from one another."

HENRY D. ROGERS.

1842. In their classic memoir "On the Physical Structure of the Appalachian Chain,"* the brothers Rogers say:

"At an early period in the geological surveys of New Jersey and Virginia, we were struck with the great prevalence of the southeasternly dip of the strata, throughout the portions of the Appalachian chain traversing those states, and recognized its dependence on the oblique or inverted folding of the strata. This will appear from the descriptions we have given in our Annual Reports for 1837 to 1839. The important general law of the greater steepness of the dip on the northwestern than on the southeastern sides of the anticlinal axes, became known to us at the same stage of our inquiries and was first announced in the Final Report on the geology of New Jersey, written in 1839, and published early in the spring of 1840" (p. 481).

Another anouncement of these views was made to the American Philosophical Society in January, 1841. †

After adverting to the statements of previous writers that all the strata between the Hoosac mountain [Massachusetts] and the Hudson river lie in an inverted order, drawings were exhibited, proving the existence of numerous closely folded anticlinal and synclinal axes; and the inference was drawn that the inverted dip of the rocks is a result of a folding of the beds at short intervals, and not of one general turning over of the whole series, as suggested by professor Hitchcock. Subterranean igneous action was referred to as having caused this compression and folding of the rocks, and its energy was shown to have been greatest along the

**Transactions of the Association of American Geologists and Naturalists*, 1840, 1841 and 1842 pp. 474-531.

†*Proc. Amer. Phil. Soc.*, Jan. 1, 1841.

Berkshire valley, and the ridges lying to the east. To the same agency was attributed the crystalline condition of the Berkshire marble and of the associated schists and semi-vitrified quartz rock— the first being regarded as merely the blue limestone of the Hudson valley, extensively altered, and the last, a highly altered form of the white sandstone at the base of the Appalachian formations (p. 482).

Speaking of the character of the flexures in the Hudson River division, they say:

"In this belt the flexures are, for the most part, of the closely folded type, and the dip is almost invariably toward the southeast, the compressed and oblique plication of the beds extending equally to the hypogene or primary rocks of the mountains bounding the valley in the east, and to the lower formations of the Appalachian system which occupy the valley itself" (p. 486).

"A feature of frequent occurrence in certain portions of the Appalachian belt, is the passage of an inverted flexure into a fault" (p. 494). "It is an interesting general fact that the space between the axes, or, more properly, the amplitude of the undulations, increases as we cross the chain northwestward" (p. 507).

1844. These views have a bearing on the interpretation of the structure occurring on the east of the Hudson river, within the geographical limits of the Taconic system. In the light of them, professor H. D. Rogers used the following language in reference to the proposal of Emmons.*

"The fixing of a base for the Palæozoic rocks of the United States is a problem scarcely less difficult than that of determining the lower limit of the corresponding system of England, to which the admirable sagacity of Sedgwick has been so usefully directed. Do we possess, in the so-called Taconic system of rocks lying to the southeast of the unequivocally fossiliferous strata at the base of the New York or Appalachian system, an independent mass of formations of an unquestionably earlier date, or are these, on the other hand, but well known lower Appalachian strata disguised by some change of mineral type and by igneous metamorphosis? These Taconic rocks, under the form they assume along the eastern boundary of New York and the western side of Vermont and Massachusetts, have been carefully studied by Emmons, Hitchcock and Mather; all of whom appear to have arrived at different conclusions concerning them.† . . . Professor Emmons considers

*Amer. Jour. Sci. xlvii. 150. Oct., 1844.

†Professor Mather's conclusions are embodied in the preface to the report on the *Geology of the First District of New York*, 1843, p. viii. Referring to the views of the pro-

the granular quartz, slate and limestone of the Taconic hills and the Stockbridge valley as constituting a distinct group of strata. . . . His principal argument in defense of this view is, that the order of succession of the component members of the group is essentially different from that witnessed in the sandstone, limestone and slate of the Champlain division, and he denies that the theory of plication of the beds, advanced originally by myself and my brother, and applied to this very region, can reconcile the seeming want of agreement. Now it is true that the apparent order of superposition in the Taconic belt is in discrepancy with the well known succession of the Champlain formations, but this is precisely what should arise from the introduction of those complete folds or doublings together of the strata which we have conceived to exist; and I would add that the sections furnished by professor Emmons and professor Mather in their reports, if resolved by the introduction of the flexures supposed by us, will all of them display, for their western portions at least, the normal order of superposition of the Champlain rocks. This identity of the so-named Taconic System with the formations of the Hudson and Champlain valley was announced by my brother and myself, in the beginning of 1841, to the American Philosophical Society. By the aid of a section from Stockbridge towards the Hudson river, we showed the existence of numerous close anticlinal folds, and thus explained the apparent inversion of the dip, which other geologists had ascribed to one general overturning of the whole series. The plication was shown to be greater along the Berkshire valley and the ridges west; the granular Berkshire marble was identified with the blue limestone of the Hudson valley, but metamorphosed by heat, and the associate micaceous, talcose and other schists were referred, in the language of the communication, to the slates of the formation of the Appalachian system; while the

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fessors Rogers, he says: "I concur with them in this opinion. My own observations on these rocks (from the Hoosac mountain to the Hudson) and those of the Hudson valley, conducted with much care throughout their whole extent, in New York, and in Vermont and Massachusetts, through a series of years, have led me to the conclusion that they are metamorphic, and of the age of the Champlain division; that they are the altered limestones, slates and sandstones of that division . . . The white limestone containing plumbago and various crystallized minerals is another point on which there are various views. I have come to the conclusion that it is metamorphic, but in more highly metamorphic state than the dolomitic limestones of the Taconic rocks."

Chapter vii., however (pp. 422-438), is devoted to the "Taconic System". But, at the end, professor Mather remarks: "It will be observed by those who have read the preceding details in regard to the Champlain Division and the Taconic System, that they are considered to be the same rocks, the latter somewhat modified in character by metamorphic agency" (p. 438).

In the chapter on Metamorphic Rocks, he says: "In describing the Taconic rocks separately, I have yielded to the opinion of some of my colleagues who have considered them as interposed between the Champlain Division and the Primary. I can discover no evidence of any such interposition . . . " (p. 440).

semi-vitreous quartz rock of the western part of the Hoosac mountains was stated to be nothing else than the white sandstone (Potsdam sandstone) of the same series slightly altered. . . . It is true Professor Emmons has presented in his report, a series of sections of the strata exhibiting an unconformity at the passage of his Taconic into the rocks of the Champlain division, but I must take the liberty of expressing my disbelief of the existence of any such unconformity, and of observing that, in the prolongation southwestward of this altered and plicated belt, as far as the termination of the Blue Ridge in Georgia, a distance of one thousand miles, no interruption of the general conformity of the strata has ever met the observation of my brother or myself,"

"It would appear thus, that the Potsdam sandstone forms the base of the Palæozoic strata in the latitude of lake Champlain, or at least in the region of the lake and the Mohawk river" (pp. 151-152).

Professor Rogers adds some suggestions which in the light of later palæontological developments, must be regarded prophetic.

"Is this formation, then, the lowest limit of our Appalachian Palæozoic masses generally, or is the system expanded downwards in other districts by the introduction beneath, of other conformable sedimentary rocks ? From the Susquehannah river southwestward, a much more complex series of strata comes in below the bottom of the lowest limestone, than is anywhere seen northeast of the Schuylkill. In some portions of the Blue Ridge belt there are at least four independent, and often very thick deposits constituting one general group, in which the Potsdam, a white sandstone, is the second in descending order. The uppermost of these is an arenaceous and ferriferous slate, many hundred feet thick, in which the only fossil is a peculiar fucoid. Beneath this lies the Potsdam sandstone, and under this again, a mass of coarse sandy slate and flaggy sandstone, amounting sometimes to six or seven hundred feet, below which occurs in Virginia and East Tennessee,* a series of heterogeneous conglomerates. Neither of the two lowest of these masses has yet rewarded research with a single fossil" (p. 152).

* Professor Safford in his admirable digest of the "*Geology of Tennessee*" (pp. 151, 158 182) described the Potsdam group as composed of: 2c. The Knox Group of Shales Dolomites and Limestones; 2b. The Chilhowee Sandstone (Potsdam proper;) 2a. The Ocoee Conglomerate and Slates (Eozoic). Below these are the metamorphic rocks, gneiss, mica slate, syenite and chloritic slates. Dr. Safford says; "The metamorphic beds together with those of other groups that are adjacent or neighboring, all appear to follow the same law of dip and strike. The dip is, in the main, at a high angle to the southeast. . . . They all apparently belong to the same system of upheavals. . . . With reference to age, I have no reason for believing that the group within Tenesee includes the metamorphosed beds of any formation of more recent date than the Ocoee conglomerate and shales" (p. 177).

"Adjoining this great mass of arenaceous strata toward the southeast we find throughout much of the broad belt of the Blue Ridge, especially in its prolongation southwestward from the Potomac, a wide expansion of metamorphic strata intersected by innumerable veins and dykes of greenstone and other igneous materials, and displaying almost every grade and variety of alternation in texture and mineral contents. These, after long and careful observation, we have been led to consider as a group of sedimentary beds, still older than the preceding, but forming a part of one and the same unbroken series. Thus, then, in the great group of strata at the base of our lowest fossiliferous series, we are presented with similar and perhaps more striking results of igneous modifying powers than even in that portion of the Champlain system whose metamorphosed rocks constitute the Taconic group. . . . Respecting the phenomena presented in the long belt of rocks here referred to, the question suggests itself whether the so-called Taconic system instead of belonging exclusively to the Champlain division, may not, along with the western border of Vermont and Massachusetts, include also, some of the sandy and slaty strata here spoken of as lying beneath the Potsdam sandstone" (p. 153).

In his final Report on the geology of Pennsylvania, published in 1868,* professor Rogers, in speaking of the Second or Middle Belt of Gneiss, in the southern gneissic district, says: "It would seem as if these minerals had crystallized or segregated from their parent sedimentary materials, under a conflict of forces, the newly awakened crystallizing energies being not always parallel to the original bedding of the deposit, but more frequently oblique to it" (p. 71). This remark is made in view of the "wavy or minutely undulated lamination, arising apparently, from a contorted or wavy structure in the coarsely crystallized mica, its predominant mineral, which he thought, seemed "to proceed from the interference of innumerable planes of cleavage—or what is the same thing —of crystalline lamination, with the original planes of deposition of the strata."

He remarks a character which possibly might be attributed to remoteness of the upper gneisses from the zone of intense crystalline action:

*_The Geology of Pennsylvania, Government Survey._ By Henry Darwin Rogers. In two vols. 4to, New York, 1868. The author informs us in the preface that the survey was commenced in 1836; interrupted from failure of appropriations in 1842; revived in 1851 (after sundry failures in attempts to accomplish publication); the field work was concluded in 1855, report rewritten and placed in way of publication under direction of the author. The preface is dated Philadelphia, April, 1858.

"A remarkable feature in the northern or uppermost band of gneiss on the Schuylkill, or those which next adjoin the base of the Primal series, is the possession of a less than usual completeness of crystallization in the constituent minerals, the feldspar more especially, appearing to be less perfectly developed than common, and more in the condition of roundish or lenticular, segregated lumps. In this circumstance, the gneiss here approximates somewhat to the structure of the lowest beds of the Primal series, which are also porphyroidal, but exhibit their metamorphism in a far lower degree" (p. 73).

The prevailing Appalachian dip is not remarked in the gneisses:

"A remarkable feature in the structure of the whole southern gneiss district is the prevalence of a northward dip in the strata. This inclination prevails along the Schuylkill, with very few local and trivial exceptions throughout all the three great subdivisions of the zone of gneiss" (p. 78).

I make one more quotation, setting forth a conception in reference to Appalachian structure, which demonstrates long and thoughtful observation:

"That the wide area of gneiss now under description is undulated in a succession of anticlinal and synclinal waves is obvious to any practiced geological observer who studies its structure with due care. . . The notion of an undulated or folded structure in the gneiss finds corroboration in the parallel arrangement of the hills and valleys; and in the sudden changes in the dip of the strata, wherever we make a transverse section through the region; but it receives its most positive demonstration, when we study the topography and distribution of the gneiss on the western side of the county. There as we have already seen, several long tapering tongues of the gneiss formation project forward towards the W, including between them actual troughs of the Palæozoic rocks, a feature not attributable to any other mode of elevation of the gneiss than that of an undulation of its general floor in the manner of long anticlinal waves" (p. 86). In reference to inverted flexures in the South mountains, see page 94.

JAMES HALL.

1843. In his Final Report on the geology of the Fourth District of New York,* Mr. Hall, like Mr. Mather and Mr. Vanuxem,**

**Geology of New York. Part IV, Comprising the Survey of the Fourth Geological District.* By James Hall. Albamy, 1843.

**Vanuxem's chapter on the Taconic system occupies but about one page (pp. 22,23.) The rocks of the system barely entered his district. Unlike Mather, he agreed with Emmons as to the validity of its existence. The following, however, is a curious paragraph:

makes mention of the Taconic system, then recently proposed by Dr. Emmons. But, with Mr. Hall, a mere mention suffices. He says: "II. Taconic System. Represented by the Taconic range of mountains in the eastern part of New York." (p. 17.)

1847. Mr. Hall's attitude toward the Taconic was disclosed in the first volume of the Palæontology of New York* where the trilobites described by Dr. Emmons under the names *Atops trilineatus*, and *Elliptocephalus asaphoides*, as representatives of Taconic life, were described as *Calymene beckii*, an authentic species of the Hudson River group, and *Olenus asaphoides*, presumed also to be of similar age. He says:

"Supposing the existence of a system of strata below the Potsdam sandstone, of which we have no proof, we might fairly infer that the wide interval between the deposition of those strata and the Hudson River group, would give us forms of animal life more widely different than these examples offer" (p. 257, note.)

1859. So far as I have observed, professor Hall had no occasion to assume positions bearing on any questions concerning pre-Silurian rocks, until some [assumed] "Trilobites of the Shales of the Hudson River Group" from northern Vermont, were placed in his hands.† These were described as *Olenus thompsoni, Olenus vermontana and Peltura* (*Olenus*) *holopyga* (pp. 59-62). These fossils, as it appeared, were obtained from the district claimed by Emmons as representing the Taconic system. Though these were not generic types characteristic of the horizon of the Hudson River group, the controlling reason for placing them there, is expressed in the appended note as follows:

"Note. In addition to the evidence heretofore possessed regarding the position of the slates containing the trilobites, I have the testimony of Sir W. E. Logan, that the shales of this locality are in the upper part of the Hudson River group, or forming a part of a series of strata which he is inclined to rank as a distinct group, above the Hudson River proper. It would be quite superfluous for me to add one word in support of the opinion of the most able

"It is a convenient receptacle for deposits which belong neither to the Primary nor the New York System; and the mind in England is disposed to one of the kind. since the Cambrian System holds the same position. From [To] the necessity of a connecting link between the Primary and the Secondary classes, which alone existed when Werner rose as a geologist, we owe the Transition class, the fruits of which are the Cambrian System of Mr. Sedgwick. the Silurian of Mr. Murchison, and the Devonian of Mr. Phillips; now merged. with the exception, probably, of a portion of the Cambrian, in the New York System.'

**Palæontology of New York*, Volume I. By James Hall, 1847.

†*Twelfth Annual Report of the N. Y. Regents. Contribution to the Palæontology of N. Y., 1855, '56, '57 and '58.* By James Hall. 1859. Professor Hall has informed us that this report was published previous to Sept. 20, 1859.

stratigraphical geologist of the American continent" (p. 62, note.)

1860. In the Thirteenth Report of the Regents*, professor Hall changed the generic references of the three trilobites just mentioned, establishing for them, two new genera. They are here described (the first with a new figure) under the names *Barrandia thompsoni, Barrandia vermontana* and *Bathynotus holopyga.* The technical reasons for these changes are explained. In reference to geological position, he says, in a paragraph at the end:

"The geological horizon of the shales in which these trilobites occur, having been made a matter of discussion among geologists, I shall refer those interested in the subject to the forthcoming report upon the Geology of the State of Vermont, by Professor E. Hitchcock," (p. 119, see anté, p. 99).

1861. This reference of the Georgia trilobites a horizon as high as the Hudson River group, was questioned and somewhat sharply criticised by M. Barrande† in 1860. Professor Hall, accordingly, made a restatement of the reasons which induced him to refer the Georgia trilobites to the Hudson River horizon. The truth of history, not to say justice to professor Hall, demands the quotation of some passages.‡ After stating that Sir William Logan had authorized in an explicit manner, the note appended to his paper in the *XIIth Regents' Report,* he proceeds:

"Later discoveries in the limestones associated with the shales at Quebec leave no longer a doubt, if any could have been entertained before, that the shales of Georgia, Vermont, are in the same relative position [i. e., of Quebec age, instead of Hudson River] and we must regard these three trilobites as belonging to the same fauna with the species enumerated by Sir William Logan as occurring in the Quebec group. Left to palæontological evidence alone, there never could have been a question of the relations of

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**Appendix. Contributions to Palæontology, 1858 and 1859, with additions in 1860.* By James Hall. This report, according to a slip attached to *XIVth Report*, was published before Dec. 17, 1860.

†*Neues Jahrbuch für Geologie und Petrefaktenkunde.* A translation of the letter written under date of Paris, July, 16,1860 to Prof. Bronn is given by M. Marcou, in a memoir entitled "On the Primordial Fauna and the Taconic System. By Joachim Barrande. With additional notes." From the *Proceedings of the Boston Society of Natural History*, vol. vii., Dec., 1860, pp. 360-382. Republished in *Amer. Jour. Sci.*, II., xxxi, pp. 212-15, Mar., 1861. M. Barrande wrote of these fossils: "Their primordial nature cannot admit of the least doubt, when the descriptions are read, accompanied with wood engravings which the large dimensions of these three species render sufficiently exact......All the characters of these three trilobites, as they are recognized and described by J. Hall, are those of the trilobites of the Primordial fauna of Europe. . Such is my profound conviction, and I think any one who has made a serious study of the trilobitic forms, and of their vertical distribution in the oldest formations will be of the same opinion" (pp. 371-372.)

‡*Amer. Jour. Sci.*, II, xxxi, pp. 220-6, March, 1861; *Canad. Naturalist*, vi, 113-20, Apr. 15, 1861; Geol. Vermont, i, 382-6.

these trilobites, which would at once have been referred to the Primordial types of Barrande.

"Sir William Logan yields to the palæontological evidence, and says, 'there must be a break.' He gives up the evidence of structural sequence which he had before investigated, and considered conclusive; and having heretofore [myself], relied upon the opinion of the distinguished geologist of Canada, in regard to a region of country to which my own examinations had not extended, I have nothing left me but to go back to the position sustained by the palæontological evidence." *

He then examines the palæontological evidence, and from a tabular exhibit of Quebec fossils, concludes:

"In the table we find, of previously recognized tribolites of the primordial faunæ, four genera and eight species; two genera before known in the Potsdam sandstone, and seven species; and of *Agnostus*, which is of the first and second faunæ, two species; and one new genus, with nine species."

"These are certainly very curious results; and a modification of our views is still required, to allow four genera and eight species, or, leaving out *Amphion*, three genera and six species of tribolites of the second fauna, to be associated with two genera and five species of tribolites of the primordial fauna, and yet regard the rocks as of primordial origin" (pp. 224). . . .

"In the present discussion, it appears to me necessary to go further, and to inquire in what manner we have obtained our ideas of a primordial or of *any* successive faunæ. I hold that in the study of the fossils themselves, there were no means of such determination prior to the knowledge of the stratigraphical relations of the rocks in which the remains were enclosed. There can be no scientific or systematic palæontology without a stratigraphical basis. Wisely then, and independently of theories, or of observations and conclusions elsewhere, geologists in this country had gone on with their investigations of structural geology. The grand system of Professors W. B. and H. D. Rogers had been wrought out, not only for Pennsylvania and Virginia, but for the whole Appalachian chain, and the results were shown in numerous carefully worked sections. In 1843, '44 and '45, I had myself, several times crossed from the Hudson river to the Green mountains, and found little of importance to conflict with the views expressed by the Professors Rogers in regard to the chain farther south, except in reference to the sandstone of Burlington, and one or two other points, which I then regarded as of minor importance."

* *Amer. Jour. Sci.*, II, xxxi, 221.

"Sir William Logan had been working in the investigation of the geology of Canada; and better work in physical geology has never been done in any country."

"This, then, was the condition of American geology, and investigators concurred, with little exception, in the sequence based on physical investigations. As I have before said, our earliest determinations of the successive faunæ depend upon the previous stratigraphic determinations. This, I think, is acknowledged by Mr. Barrande himself, when he presents to us as a preliminary work, a section across the centre of Bohemia. With all willingness to accept Mr. Barrande's determination, fortified and sustained as it is, by the exhibition of his magnificent work upon the trilobites of these strata, we had not yet, the means of parallelizing our own formations with those of Bohemia by the fauna there shown. . . . It then became a question for palæontologists to decide whether determinations founded on a physical section, in a disturbed and difficult region of comparatively small extent [i. e. Sir W. E. Logan's on the borders of Canada and Vermont] were to be regarded as paramount to determinations founded on examinations, like those of the Professors Rogers, extending over a distance in the line of strike of five or six hundred miles; and those of Sir William Logan over nearly as great an extent, from Vermont to Gaspe." . . .

"It is evident that there is an important and perplexing question to be determined. . . For myself, I can say that no previously expressed opinion, nor any 'artificial combinations of stratigraphy previously adopted, by me, shall prevent me from meeting the question fairly and frankly" (pp. 224-5-6).

1862. The new evidences in reference to the age of many of the rocks in the valley of the Hudson, led professor Hall to an abandonment, at least for a time, of the use of the term Hudson River group, for the assemblage of strata next above the Trenton group. In a note at the end of his report on the geology of Wisconsin, he records this changed position.*

"At that time [when the final reports on the geology of New York were in preparation] and at a later period, Dr. Emmons proposed the name Taconic System for a series of rocks lying a considerable distance to the eastward of the Hudson River, and which were, according to the author of that System, below the Potsdam sandstone. An examination of the slaty rocks of the System in some of their typical localities, proved, in the opinion of the writer, that

*Report on the Geological Survey of the State of Wisconsin, vol. 1. Jan. 1862, pp. 47 and 443-5.

they rested upon the Potsdam sandstone; and in tracing the same beds toward the Hudson River, there could be discovered no break or interruption in the strata anywhere to the east of that river. . . At a subsequent period, Dr. Emmons extended the application of the term Taconic System to the rocks of the Hudson River valley, including the area originally regarded as the typical locality of the Hudson River Group. . . Within the last few years, the discussion of the subject has been revived, more particularly from discoveries of fossils in Vermont and Canada, which prove conclusively that these slates are to a great extent, of older date than the Trenton limestone."

"Looking critically at the localities in the Hudson valley which yield the fossils [belonging to the second fauna] we find them of limited, and almost insignificant extent. . . Besides the fossils just mentioned, we know of no others for nearly a hundred miles along the Hudson valley, with the exception of the Graptolites, which have heretofore been referred to the age of the other fossils found in the smaller outliers, or to the second fauna, but which in reality, hold a lower position, and belong to the great mass of the shales below."

"Until recently but one or two other species of known older types of fossils (those of the Primordial fauna) had been discovered in these slates. But within the past few years, the number discovered has been very great. . . We are therefore satisfied. . . that the term Hudson River group cannot properly be extended to . . . the Lorrain shales and the shales and sandstones of Pulaski, etc. . . I have therefore dropped the term Hudson River group in its application to the rocks of Wisconsin which are of the age of the Lorrain shales of New York, and the 'blue limestone' of Ohio." . .

1864. The field examination made in 1864 in company with Sir W. E. Logan, has already been mentioned. *Ante'*, p. — This resulted in the recognition of a wide distribution southward, of rocks belonging to the Quebec and Sillery formations. These identifications were made in the midst of a region which had generally been regarded as underlaid originally by altered strata of Hudson River age.

1877. The conclusions reached in 1861 and 1862, in reference to the age of the mass of rocks along the east side of the Hudson river, were found to be only partially true.* Later investigation showed the existence along both sides of the river, of a body of

*"Note upon the History and Value of the term Hudson River group, in American Geölogical nomenclature." *Proc. Amer. Assoc.*, Nashville, 1877, pp. 258-65.

slates lying in unquestionable continuity with the Lorrain shales of the Mohawk valley and the northwestern part of the state, and professor Hall therefore reclaimed the term Hudson River group as appropriate. No particular citations of reasons assigned is needed here. Professor Hall however, still recognized the existence of a mass of slates farther east in New York, which contained fossils of the Primordial fauna. These, therefore, still remained, to validate, as far as they could, Dr. Emmons' contention for the existence of a pre-Silurian, fossiliferous system.

SIR WILLIAM LOGAN.

1845. The first record of observations made by Sir William Logan on the range of rocks here under consideration*, speaks of them collectively, as the "Metamorphic Series." But he recognizes a lithological and chronological subdivision.

"To the south of the Mattawa and of the Ottawa in its continuation after the junction of the two streams, important beds of crystalline limestone become interstratified with the syenitic gneiss,and their presence constitutes so marked a character that it appears expedient to consider the mass to which they belong as a separate group of metamorphic strata, supposed, from their geographical position and general attitude, to overlie the previous rock conformably. The limestone beds appear to be fewer at the bottom than at the top of the group, but whether few or many, they are always separated by beds of gneiss which in no way differ in constituent quality or diversity of arrangement from the gneiss lower down, except in regard to the presence of accidental minerals, the most common of which are garnets," (pp. 41, 42).

The facts stated would seem to afford but slender ground for the recognition of two "groups."

But this grouping is traced over an extent of sixty-three miles, when the result of his observations is expressed in the following arrangement:

4. Fossiliferous limestone [with Niagara fossils.]
3. Greenish sandstones [of undetermined relations.]
2. Chloritic slates and conglomerates [subsequently Huronian.]
1. Gneiss (p. 67.)

1846. The series on the north shore of lake Superior is further described in the report of the following year†. The order of succession determined is given below:

5. Sandstones, limestones, indurated marls and conglomerates, interstratified with trap.

**Report of Progress of the Canada Geological Survey for 1845-6*, pp. 40-45.
†*Report of progress for 1846-7*, pp. 8-17.

4. Bluish slates or shales, interstratified with trap. [Huronian Animike.)
3. Chloritic and partially talcose and conglomerate slates.
2. Gneiss.
1. Granite and syenite.

On these Mr. Logan makes the following remarks:

"The rock at the base of the series is a granite, frequently passing into a syenite by the addition of hornblende; but the hornblende does not appear to be often present wholly without the mica. . . This granite appears to pass gradually into a gneiss, which seems to participate as often in a syenitic as a granitic quality. . . The gneiss is succeeded by [3] slates of a general exterior dark green color, often dark gray in fresh fractures, which at the base appear occasionally to be *interstratified* with beds of a feldspathic quality, of the reddish color belonging to the subjacent granite and gneiss. . . Some of the beds have the quality of a greenstone, others, that of a mica slate, and a few present the character of quartz rock. Rising in the series, these become [4] interstratified with beds of a slaty character, holding a sufficient number of pebbles of various kinds to constitute conglomerates. The pebbles seem to be of various qualities, but apparently all derived from hypogene rocks. . . [Ogishke conglomerate?] "The formations which succeed [5] rest *unconformably* upon those already mentioned. The base of the lower one where seen [in Thunder Bay] in contact with the subjacent green slates presents conglomerate beds, probably of no great thickness, composed of quartz pebbles chiefly, with a few of red jasper, and some of slate in a green arenaceous matrix, consisting of the same materials in a finer condition." [Afterward "slate conglomerate."]

The [5] sandstones, limestones, indurated marls and conglomerates, are said to be crowned by an enormous amount of volcanic overflow.

In the light of our own studies, it becomes easy to recognize in No 3 the rocks of the Keewatin iron-bearing series, represented on the south shore by the Marquette iron-bearing series; in No. 4, the chloritic diabase slates of the Thessalon valley, and in No. 5, the "slate conglomerate" and quartzites and Trap-rocks of the same regions, and the Animike slates of northeastern Minnesota,* while the crowning overflow is the great gabbro sheet so widely spread in northern Minnesota.

*Erroneously supposed by Whitney and Wadsworth to represent the Cupriferous formation of the south shore (*Azoic Rocks*, p. 334). As the Cupriferous is with them of Potsdam age, we should have an astonishing equivalency between the Potsdam sandstone and the Animike black slates.

It is important to keep in mind the early recognition of an unconformity between the two series of schists Nos. 3 and 4, and the existence of quartzose pebbles in the bluish slates,* as in the blackish slates of the Thessalon valley.

1847. In order to describe the grounds of director Logan's determinations respecting the geology of the region north of lake Huron it is necessary to make a quotation from Mr. Murray's report of a survey in 1847.†

"The older groups observed, consist firstly, of a metamorphic series composed of granitic and syenitic rocks in the forms of gneiss, mica slate and hornblende slate; and secondly, of a stratified series, composed of quartz rock or sandstones, conglomerates, shales and limestones. . . . On a cluster of small islands, . . . granite was found breaking through the quartz rock. The color of the rock [which rock ?] was red. On one of the islands, quartz rock beds on opposite sides of the granite, were observed to dip in opposite directions, north on the north side, and south on the south side, at an angle of 78° or 80°; and in another of the islands, the quartz rock and granite were seen in juxtaposition, the former reclining on the latter. In this case the quartz was traversed by several trap dikes running slightly oblique to the strike, while granitic veins ran transversely through the whole, and were continued through the main body or nucleus of the granite, the one granite being distinguishable from the other notwithstanding the red color of both, by the finer texture of the veins" (pp. 112, 113).

This is the earliest description of a portion of the rocks in what was to become "the original Huronian region." An examination of the statements made by Mr. Murray justifies the conclusion that the rocks described correspond to the 'upper group' found by Logan on the north shore of lake Superior. But it will be seen that Logan parallelizes them with the *metamorphic* series of the north shore, without paying due regard to the unconformity which he has described running between the upper and lower

* These are described as *black* argillaceous slates by Mr. Alexander Murray (same report, pp. 51-3) After noticing the two groups and the structurally *conformable* passage of the lower into the bottom gneisses, he says of the upper (black argillaceous slates) "The base of this formation . . . was observed on the Kaministiquia, near the Grand Falls. Its immediate junction with the rock on which it reposes was concealed from view, but appears to be indicated by the position of a small lake or pond occurring just below the second portage, and the marshy ravines which run from it in the direction of the strike on each side. The slates visibly reach to within a short distance of the pond, probably brought into place against the syenite by a dislocation.

† Murray, *Report of Progress for 1847-8.*

groups. Thus, in reference to the second series of Mr. Murray, he writes in 1848: *

"The series of rocks occupying this country form the connecting link between lakes Huron and Superior to the vicinity of Shebawenahning, a distance of 120 miles, with a breadth in some places of ten, and in others exceeding twenty miles, and it appears to me, must be taken as belonging to one formation; on the west it seems to repose on the granite which was represented in my report on lake Superior as running to east of Gros Cap, north of Sault Ste. Marie; on the east, the same supporting granite was observed by Mr. Murray, north of La Cloche, between three and four miles in a straight line up the Rivière au Sable, . . . and again about an equal distance up another and parallel tributary, . . . in both cases, about ten miles from the coast. . . . In respect to the geological age of the formation, the evidence afforded by the facts collected last year by Mr. Murray, . . . is clear, satisfactory, and indisputably conclusive. . . . The chief difference in the copper-bearing rocks of lakes Huron and Superior seems to lie in the great amount of amygdaloidal trap present among the latter, and of white quartz rock or sandstone among the former. But on the Canadian side of lake Superior, there are some considerable areas, in which important masses of interstratified greenstone exist without amygdaloid, [this is the 'upper group'] while white sandstones are present in others, as on the south side of Thunder Bay, though not in the same state of vitrification as those of Huron. But notwithstanding these differences, there are such strong points of resemblance in the interstratification of igneous rocks, and the general mineralized condition of the whole, as to render their positive approximate equivalence highly probable, if not absolutely certain; and the conclusive evidence given of the age of the Huron, would thus appear to settle that of the lake Superior rocks, in the position given to them by Dr. Houghton, the late state geologist of Michigan, as beneath the lowest known fossiliferous deposits, a position which, as will be seen by a reference to the Report of Progress I had the honor to submit to your Excellency, in 1846, appeared to me to derive some support from evidences on the Canadian side of lake Superior itself."

The positive error embodied in the foregoing paragraph is the attempt to parallelize the Huron rocks with a series of Superior rocks which consists of two groups, and then having shown the parellelism with the higher group, the drawing of inferences touching a

* *Report on the north shore of Lake Huron*, Dec. 29, 1848, pp. 8, 9, 19, 20.

third geological region which are valid only in reference to the lower Superior group.

The foregoing citation from the report of 1848, was embodied in a communication made by director Logan to the British Association in 1851.* But in place of the last part of the last sentence, we find the following: "and in this sequence, those [rocks] of Lake Huron, if not those of Superior, would appear to be contemporaneous with the Cambrian series of the British Isles." In the next paragraph, he says the Lower Silurian, on the lower St. Lawrence, "appears to rest upon gneissoid rocks, without the intervention of the Cambrian" (*Amer. Jour. Sci.*, l. c., p. 226;) and in the next, he uses the phrase, "Cambrian formation of Lakes Huron and Superior" (p. 227), and the same again on the next page. It is clear then, that in 1851, Sir William Logan considered the rocks on the north shore of lake Huron as equivalent to the Cambrian of Sedgwick.

1848. We must again cite from Murray, as it appears that director Logan's judgments were largely based on assistant Murray's facts. In the report for 1848–9, after describing the country along the Spanish river, he says:

"The geological formations met with in the region thus described, may be arranged in two groups, one of which appears to be nearly allied to, and the other identical with, the older rocks of which mention was made in my report of 1847–8. They are

2. Quartz rock group.
1. Granitic or Metamorphic group.

Mr. Murray, in describing the lower group, mentions only granitoid rocks. He says: "The constituent minerals were usually those of granite or syenite, or a mixture of both. . . A gneissoid structure was observed on one or two occasions, . . but obscure and ill defined." Speaking of the "Quartz rock group," he says:

"The rocks of this group, where they came under our observation, like those examined the previous season, were found to be partly of aqueous and partly of igneous origin." After describing the quartzose members, he speaks of the slate. "The slates were gray, green or blackish in color, and were usually more or less silicious, and frequently very micaceous. . . The more purely argillaceous portions of the slate were generally *black* or of a *very dark brownish* tinge, and in these a very symmetrical jointed structure, dividing the rock into rhombohedral forms of considerable regularity, was frequently recognized. The slates were very

*Rep. Brit. Assoc. Adv. Sci. 1851. Trans. Secs. 59-62 *Amer. Jour. Sci.* II, xiv, 224-229. See also *Bull. Soc. géol. de France*, 1849-50, (2), vii, 207-209.

often observed to pass into a conglomerate, holding pebbles of granite and syenite chiefly, varying in diameter from an eighth of an inch to a foot, and imbedded in a *black argillaceous matrix*" (p. 37.)

No one who has seen Logan's slate conglomerates in the valley of the Thessalon, can fail to recognize the identity of the argillaceous slates described by Mr. Murray.

1849. In the report for 1849–50, director Logan describes the geology about Bay St. Paul and Murray bay. He classifies the rocks as follows:

4. Bituminous limestone (Trenton.)
3. Calciferous sandrock.
2. White quartz rock (Potsdam sandstone.)
1. Metamorphic group (p. 8.)

Referring to the "Metamorphic group," he states that the prevailing rock of the country is gneiss, sometimes of a granitic and sometimes of a syenitic character. After careful local details, he says:

"The gneiss of this district belongs to that metamorphic group of rocks, which in previous reports has been described as existing on the Ottawa, and as traceablé thence . . to Cape Tourmente below Quebec. . . None of the highly crystalline limestones which on the Ottawa are so marked a feature of the group, were observed in the region under attention."

This fact gives support to the suggestion of Whitney and Wadsworth that the Laurentian limestones may be mere segregations, instead of extensive strata.

A white, translucent, slaty quartz rock, rendered cleavable by the presence of silvery mica, but seen only at three points, directly overlies the gneiss. "There appears to be little doubt that this rock is equivalent to the Potsdam sandstone of New York" (p. 10.)

1851. This year director Logan and assistant Murray examined different portions of the district between the Ottawa and the St. Lawrence. Mr. Logan describes the Potsdam sandstone as reposing unconformably on the "Metamorphic or gneissoid group" (p. 6.) The character of this "group" may be learned from Mr. Murray's description of the geology of Rigaud mountain (*Report of Progress*, p. 63.) After speaking of the occurrence of gneisses, he says:

"These beds are *interstratified* with others of a different character; one set is composed of small cleavable forms of black hornblende and grains of translucent, yellowish-white feldspar, weathering opaque-white, and crystals of brown mica. Another consists of grayish-green cleavable pyroxene, with individuals of greenish

feldspar weathering white, and largely disseminated grains of magnetic iron; and a third consists of translucent albite, with black hornblende and magnetic iron ore disseminated, alternating with micaceous layers. All these beds are intersected by transverse dykes, some of which are fine-grained, grayish-black trap, probably a greenstone with disseminated grains of calc-spar, while others are porphyritic, having a fine grained blackish-green base, with individuals of greenish white feldspar" (pp. 63-64.)

This passage sounds very unlike the descriptions of the rocks about Spanish and Thessalon rivers. But these are the rocks which in the Seigniory of Rigaud, rest directly upon the gneisses. It is further stated (pp. 60, 65,) that at the base of 71 feet of sandstone, on Bluff island in Charleston lake, is a "red talco-quartzose rock of the Metamorphic series." No such rock is described in the region north of lake Huron. There is reason to suppose another group of rocks rests in this region in a position between the gneiss and the "Huron rocks."

Of the deeper gneisses Mr. Murray supplies some interesting information:

"Near Furnace Falls, on the second lot of the eighth concession of Landsdowne, there is a considerable display of crystalline limestone, holding as usual, spangles of graphite and mica, with grains of quartz. . . Crystalline limestones are also, extensively exhibited in the neighborhood of Beverly, township of Bastard, and Newboro' in south Crosby. Their color is usually white, but sometimes grayish-white, or white with gray bars or stripes. Small scales of graphite are invariably disseminated through the rock, with serpentine, mica and iron pyrites. . . The texture of the limestones is usually coarse. . . Nodular masses of vitreous white quartz, surrounded with thin layers of brown mica, and both enclosed in foliated green pyroxene, are met with in some of the beds. . . On the twenty-fourth lot of the tenth concession of Bastard, there is an unmistakable bed of *conglomerate*, interstratified between two beds of highly crystalline limestone, showing the sedimentary origin of the Metamorphic series. The following is a condensed statement of the section given (p. 62.)

7. Crystalline limestone, white, coarse-grained, 6 ft.
6. Crystalline limestone, fine, very hard, bluish-gray, 4in.
5. Calcareous sandstone, fine-grained, 2 in.
4. Coarse conglomerate. The pebbles are flat and lie on their sides, etc., 1ft. 6in.
3. A calcareous aggregate of quartz, with feldspar, calc spar and scales of graphite, 2in.

2. An aggregate of colorless, translucent quartz, with feldspar and patches of greenish, chloritic limestone, with brown mica, 4in.

1. Pure white, highly crystalline, coarse limestone, 5ft.

1852. Director Logan returns to an exposition of the rocks north of lake Huron,* and states:

"On Lake Huron, the Lower Silurian group rests unconformably upon a silicious series, with only one known band of limestone, about 150 feet thick, with leaves of chert in abundance, but as yet, without discovered fossils. This series is supposed to be of the Cambrian epoch. It comprehends the Copper-bearing rocks of that district, and with its igneous, interstratified masses, has a thickness of at least 10,000 feet. The gneissoid group, of which mention is made, is probably still older than this. Its conditions appear to me to make it reasonable to suppose that it consists of aqueous deposits in an altered state."

1854. The first announcement of the term Laurentian, as the designation of a series of rocks, was made in 1854.†

"The name which has been given in previous reports to the rocks underlying the fossiliferous limestones in this part of Canada, is the "Metamorphic series;" but inasmuch as this is applicable to any series of rocks in an altered condition, and might occasion confusion, it has been considered expedient to apply to them for the future, the more distinctive appellation of the *Laurentian series*,‡ a name founded on that given by Mr Garneau, to the chain of hills which they compose."

In the same report, Mr. Murray, writing of the region between lake Ontario and lake Simcoe, supplies a general description of the Laurentian series, in these words:

"They consist of masses of micaceous and hornblendic gneiss, and masses of crystalline limestone interstratified by gneiss. In

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Quar. Jour. Geol. Soc., viii, 210, 1852.

†*Report of Progress, Geolog. Surv. Canada, for the year 1852-3*, Quebec, 1854, p. 8.

‡The term "Laurentian" had already been applied, in 1851, by Edward Desor, to the fossiliferous marine Drift of the valley of the St. Lawrence river (*Proc. Boston Soc. Nat. Hist.*, Feb. 19 and March 5, 1851, vol. IV, pp. 29, 33.) It was also published in the *Bulletin of the Geological Society of France* in the same year and in 1852; in the Neues Jahrbuch for 1853; and in Thompson's *Natural History of Vermont*, in 1853.

The term "Algonquin terrane" was also preoccupied by Desor, in 1851, as the designation of the fresh-water deposits about the Great Lakes, to which C. H. Hitchcock and J. D. Dana have since applied the term Champlain. The name "Algonkian" has been (in 1889) proposed by C. D. Walcott, for all the sub-Cambrian deposits down to the top of the crystalline schists. Thus a notable parallelism exists in the fortunes of the two terms proposed by Desor, for two distinct members of the Quaternary.

For a history of the use of the term "Laurentian as applied to a Quaternary terrane," see Joseph F. James in *American Geologist*, Jan. 1890. pp. 29-35; also C. H. Hitchcock, in *American Geologist*, April 1890, and Jules Marcou, in *American Geologist*, vol. VI, p. 64.

the great masses of gneiss, the prevailing color appears to be reddish, but they are frequently striped with interstratified bands of gray, the reddish part taking its general aspect from the reddish feldspar which is the principal constituent, while the gray is chiefly made up of small grains of white quartz and feldspar, with small scales of black mica, and occasionally grains of black hornblende. . . Beds also occur of which almost the only constituent is white quartz, and these often alternate with thin layers of yellowish white feldspar," (pp. 81, 82).

Various beds of crystalline magnesian limestone are described:—One on Eel lake 30 feet thick, and several other exposures on the same lake (pp. 83, 84); another on Long lake, seventh lot of ninth concession (with little magnesia), with apatite, silvery mica and graphite, and a few grains of rose-colored quartz, and some green serpentine; another below this, on Gold lake, with abundant grains and nodules of greenish serpentine; another, still lower, of white dolomite, with pinkish streaks and spots, with grains of quartz and serpentine (p. 84). Many other exposures are described, of similar general character. "Southwest from the Gold Lake limestone, in the continuation of the general strike, an exposure was met with on the fourth lot of the eighth concession. . . From the vicinity of this exposure, crystalline limestone is traceable, emerging from beneath the fossiliferous formations for a mile and a half" (p. 85).

If then these limestones are "low" in the gneissic series, an occurrence so near the fossiliferous limestones would imply the absence of a large part of the gneissic and the whole of the schistic rocks.

At an exposure on Birch lake, Mr. Murray measured a section, of which the following is a synopsis: (p. 89.)

11.	Mica slate, fine, with bands of coarse, disintegrating limestome	86ft.
10.	Limestone, coarse, disintegrating	40
9.	Feldspathic quartz rock and coarse disintegrating limestone	50
8.	Red, ferruginous mass, of brecciated appearance [See also p. 94]	10
7	Crystalline limestone, coarse, disintegrating	30
6.	Crystalline limestone, coarse, with graphite nodules and angular fragments of quartz	100
5.	Concealed from view	231
4.	Gneiss, mostly quartz, some black and brown mica and abundant garnets [Not very good gneiss]	260

3.	White quartz and fine-grained feldspar alternating.	130
2.	Supposed to be chiefly mica schist................	300
1.	Gneiss, red and gray, thin bedded, with layers of mica schist....................	132
		1369

1857. The reports of the Canadian survey for 1853, '54, '55, '56 were not printed until 1857.* In Murray's reports for 1853 and 1854, he describes the country between Georgian bay and the Ottawa river. "The Laurentian series" occupies most of the country. He speaks of *gneiss in alternation with mica slate.* Some highly garnetiferous portions are mostly an aggregation of granular quartz. He speaks also, of a black rock composed chiefly of hornblende, with some black mica (pp. 89, 90.) A fine grained red rock, supposed to be intrusive (p. 90) is spoken of, and beds of limestone are particularly located (pp. 91, 92, 93.) Bands of limestone are found about lake Nipissing (pp. 121, 122, 123.) The "Laurentian series" of lake Nipissing is further described in Murray's reports for 1855 and 1856 (Rep. 1857, pp. 140-3.)

"Among the boulders on lake Nipissing" says Mr. Murray, at the end of the report for 1855—printed in 1857, "many were observed to be of a slate conglomerate, and they were frequently of very great size; in their aspect and general character, these have a very strong resemblance to the slate conglomerate of the *Huronian series*,† from which, in all probability, they are derived" (p. 125.) In the report for 1856, he speaks of the bowlders of metamorphic rocks as derived from the Laurentian and Huronian formations on the north shore of lake Huron (p. 134.)

In reference to the red rock first mentioned in the report for 1853, (p. 90,) he says:

"At Grand Recollet Fall, in the north channel of the French River, and in the south channel about two miles southeast from them, the rock is of a brick red color, without any distinguishable lines or layers of stratification. It was supposed to be an intrusive syenite, and with a general breadth of from one to two miles, its course appeared to be N. N. W. and S. S. E., (141, 142.)

*The volume printed in 1857, of 494 pages, contains reports of Murray and Hunt for 1853, 1854, 1855, and 1856, and reports of Mr. Billings and Mr. Richardson for 1856.

†The term "Huronian" is evidently employed in this place, as a geographical designation, rather than the name of a well-considered historical assemblage of rocks occurring in the Huronian area and elsewhere. Systemically, these rocks were understood by Sir William Logan, as he tells us, to belong to the Cambrian (See *ante*, p. 116, 1852, in *Rep* for 1851.) It will be remembered also, that Emmons had declared that they fall within the limits of the Taconic (See *ante*, p. 82, 1860, p. 18;) and it does not appear that the insistance upon the use of term Huronian has been formally defended—a lack of any attempt at justification which is explained only by the apparent assumption that the claims of Taconic were too preposterous to merit consideration.

Director Logan, in a note, suggests the resemblance of this red rock to some of the harder kinds of the *laterite* rock of the East Indies. He cites Dr. Clarke, as concluding, in 1838, that it results from decomposed syenite or hornblendic gneiss. "The Canadian rock," Mr. Logan adds, "seems to be a syenite in an incipient state of decomposition."

In his report for 1856, dated 1st March, 1857, Mr. Murray, speaking of the "distribution of the rock formations" between lake Nipissing and lake Huron, says:

"The rocks of the region explored during the season, embrace two of the oldest recognized geological formations, the Laurentian and Huronian; the rocks of the latter and more recent of which, have been observed to pass unconformably below the lowest of the fossiliferous strata of the Silurian system. The contorted gneiss of the Laurentian series, with its associated micaceous and hornblendic schists, spreads over the country to the south and east, while the slates, conglomerates, limestone, quartzyte and greenstone of the Huronian, occupy the north and western part" (p. 168). The boundary between the two coincides approximately with the White Fish river. The *immediate contact was nowhere distinctly seen* (168, 171). In passing "from the lower to the higher formation, a mass of rather coarse grained greenstone was generally met with." Mr. Murray gives, with many doubts, an approximate section of the Huronian series (p. 172), from which the following statement (omitting interpolated trap beds) is condensed:

6. Quartzyte, white and very pale sea-green, with beds of quartz conglomerate, the pebbles generally white opaque quartz, but sometimes red and green jasper.
5. Green, silicious, chloritic slates, and bands of quartzyte.
4. Slate conglomerate.
3. A band of limestone, much disturbed, often brecciated, pale whitish gray to dark blue.
2. Slate conglomerate, matrix always greenish, sometimes slaty, sometimes resembling a massive, fine grained greenstone; with many pebbles of white and red syenite, and occasional rounded masses of green, brown and red jasper.
1. Slate, fine grained, green, silicious with thin bands of green quartzyte; also, fine grained slates, sometimes greenish, often bluish or black, weathering very black; occasionally some layers of a reddish color.

The total thickness is supposed to be about 10,000 feet (p. 186). The dips of the rocks of this series are generally under 45°, but they locally vary from horizontal to 90°. The strikes vary from

east northeast to west northwest. It appears to be a region of general disturbance. "An immense mass of magnetic trap" was found on White Fish lake. This is about midway between lake Wahnapitæ and island La Cloche in lake Huron, this, according to Hunt's analysis, contains "magnetic iron ore," magnetic iron pyrites" and "titaniferous iron." These facts remind one of the titaniferous and magnetic gabbro of northeastern Minnesota. Limestones are seen on the shore of lake Panache (p. 183). The eastern extremity of the La Cloche mountains is in a white or greenish quartzyte (p. 185).

Director Logan's report dated 3d March, 1857, after summarizing the work of Mr. Murray for the last five years, proceeds to trace the limestone beds of the "Laurentian Formation" in the neighborhood of Grenville and the Calumet river.

In a paper read before the American Association, in August, 1857,* by Sir William E. Logan "On the Division of the Azoic Rocks of Canada, into Huronian and Laurentian," he speaks of them confidently as "a series of very ancient sedimentary deposits in an altered condition." He refers to his suggestion of 1845, to separate the purely gneissoid portion from the portion consisting of interstratified gneisses and limestones, but says the evidence does not permit him to decide certainly which division is most ancient.

He next refers to what was published in the report of 1845, relative to the rocks on lake Temiscaming, consisting of silicious slates and slate conglomerates, overlaid by pale sea-green or slightly greenish-white sandstone, with quartzose conglomerates. The slate conglomerates are described as holding pebbles and bowlders (sometimes a foot in diameter) derived from the subjacent gneiss, the bowlders displaying red feldspar, translucent quartz, green hornblende and black mica, arranged in parallel layers which present directions according with the attitude in which the bowlders were accidentally inclosed. From this it is evident that the slate conglomerate was not deposited until the subjacent formation had been converted into gneiss, and very probably greatly disturbed; for while the dip of the gneiss, up to the immediate vicinity of the slate conglomerate, was usually at high angles, that of the latter did not exceed nine degrees, and the sandstone above it was nearly horizontal."

"In the Report transmitted to the Canadian Government in 1848, on the north shore of Lake Huron, similar rocks are described as

* *Proc. Amer. Assoc. Adv. Sci.*, 1857, II, pp. 44-47.

constituting the group which is rendered of such economic importance from its association with copper lodes. This group consists of the same silicious slate and slate conglomerates, holding pebbles of syenite instead of gneiss; similar sandstones [quartzites?] sometimes showing ripple marks, some of the sandstones [quartzites?] pale-red green, and similar quartzose conglomerates, in which blood-red jasper pebbles become largely mingled with those of white quartz, and in great mountain masses predominate over them. But the series is here much intersected and interstratified with greenstone trap, which was not observed on Lake Temiscaming. These rocks are traced along the north shore of Lake Huron from the vicinity of the Sault Ste Marie, for 120 miles east." Sir William Logan continues, and indicates the existence of the same formation northeastward 130 miles farther, and as far as the Sturgeon river. The general bearing is northeast, and the dip appears to be almost northwest.

It would be erroneous to suppose that director Logan intended, in the foregoing citation, to say that the gneiss is *immediately* "subjacent" to the slate conglomerate containing gneissic pebbles. No contact between the slate conglomerate and the subjacent gneiss had been reported and it was impossible to affirm that the formation here described was chronologically successive to the gneiss.

"The group on Lake Huron," he continues, "we have computed to be about ten thousand feet thick, and from its volume, its distinct lithological character, its clearly marked date posterior to the gneiss, and its economic importance as a copper-bearing formation, it appears to me to require a distinct appellation, and a separate color on the map. Indeed, the investigation of Canadian geology could not be conveniently carried on without it. We have, in consequence, given to the series, the title of *Huronian*."

"A distinctive name being given to this portion of the Azoic rock, renders it necessary to apply one to the remaining portion. The only local one that would be appropriate in Canada is that derived from the Laurentide range of Mountains, which are composed of it from Lake Huron to Labrador. We have therefore designated it as the *Laurentian* series.*

Thus a new meaning was given to the term "Laurentian series," which, since 1854, had included all the Azoic rocks.

At the same meeting of the American Association, Sir William Logan read a paper, "On the probable subdivision of the Lauren-

*See also, *Canadian Journal*, 1857, ii, 439-442; *Canadian Naturalist and Geologist*, 1857, ii, 255-258.

tian series of rocks in Canada."* He described two beds of limestone which he had traced in the township of Grenville, on the Ottawa, running N. N. E., with indications that they belong to opposite sides of an overturned synclinal, with anticlinals of gneiss and quartz running parallel on the north and the south. A feature of these and other outcrops of limestone "is the occurrence immediately near the limestones, of immense masses of lime-feldspar. North of the Argenteuil band, eight miles examined across the stratification, consist almost entirely of it, in the form of Labradorite. . . Lime-feldspar is abundant at St. Jerome, and its stratified character is conspicuously displayed—the beds running parallel with the limestone. Mr. Hunt has traced a band of crystalline limestone for eleven miles, running diagonally across the township of Rawdon, in a north bearing. On the west side of this, lime-feldspar forms the great bulk of the rock exposures for twelve miles across the measures, and shows a well marked stratification."

"In Chateau Richer, below Quebec, a band of limestone occurs about a mile from the fossiliferous deposits, and to the northwest of it, lime feldspars present a breadth of eight miles. On an island near Parry's Sound, on Lake Huron, Dr. Bigsby observed the occurrence, *in situ*, of the opalescent variety of Labradorite, and the name of the mineral reminds us of the existence of the rock beyond the eastern end of the Province. It thus appears probable that a range of the rock will be found winding irregularly from one end of the Province to the other, of sufficient importance to authorize its representation by a distinct color on the map, and a distinct designation in geological nomenclature." †

1860. In a letter to M. Barrande, under date of December 31, 1860,‡ Sir William Logan gives an exposition of the fauna of the Quebec group. Toward the end, he notes some recent observations which led him to qualify previous opinions in reference to the age of the Lake Superior sandstone:

"Mr. Murray has this season ascertained that the lowest rock that is well characterized by its fossils, in the neighborhood of Sault Ste Marie, near Lake Superior, really belongs to the Birdseye and Black River group, and that it rests on the sandstone of Ste Marie and Lacloche, the fossiliferous beds at the latter place being

Proc. Amer. Assoc., 1857, Pt. II, 47-51; *Canadian Journal* 1858, II, iii, 1-5; *Canad. Natur.* 1857, ii, 270-274.

†Dr. J. J. Bigsby, nevertheless, has recorded the opinion that the Huronian and Laurentian systems are intimately related in lithological character and conformable position. The reference being especially to the north shore of lake Superior (*Quar. Jour. Geol. Soc.*. 1863, xix, 36-52).

‡*Canadian Naturalist and Geologist*, v. 472-7.

tinged with the red color of the sandstone immediately below them. These underlying Lake Superior rocks may thus be Calciferous and Potsdam, and may be equivalent to the Quebec group and the black colored shales beneath. The Lake Superior group is the upper Copper-bearing series of that region [consisting of 3. Potsdam; 2. Cupriferous; 1. "Slate conglomerates" etc., of lake Huron], and rests unconformably upon the lower Copper-bearing series, which is the Huronian system [as identified about Lake Superior] . . . Professor Emmons has long maintained, on evidence that has been much disputed, that rocks in Vermont, which in June, 1859, I for the first time saw and recognized as equivalent to the magnesian part of the Quebec group, are older than the Birdseye formation; the fossils which have this year been obtained at Quebec, pretty clearly demonstrate that in this he is right."*

1863. No other record on the subject of pre-Silurian rocks appears to have been made by Sir William Logan until the publication of the Geology of Canada, in 1863. This convenient and copious synopsis of Canadian geology, has subsequently been cited for authority, instead of the original reports, and in consequence, geologists have fallen into some misunderstandings."†

"The rocks which compose the Laurentian mountains" writes Sir William Logan, "were shown by the Geological Survey, in 1846, to consist of a series of metamorphic, sedimentary strata underlying the fossiliferous rocks of the province. . . . They are altered to a highly crystalline condition, and are composed of highly feldspathic rocks, interstratified with important masses of limestone and quartzite. Great vertical thicknesses of the series are composed of gneiss containing chiefly orthoclase or potash feldspar, while other great portions are destitute of quartz, and composed chiefly of a lime-soda feldspar, varying in composition from andesine to anorthite, and associated with pyroxene or hypersthene. This rock we shall designate by the name of *anorthosite*."

It can hardly be said that the survey established the conclusion that these rocks were sedimentary in origin; but it pointed out

* This remarkable admission is alluded to by M. Barrande in these words. "Terms so clear and possitive need no commentary. It is a formal recognition by Sir W. Logan of the Taconic system at the base of the lower Silurian. Professor Emmons could not wish the assent of a more respectable authority, which cannot fail to secure the adhesion of all American geologists ("Documens anciens et nouveaux sur la faune primordiale et le système Taconique en Amérique, Bull. Soc. géol. de France, Seance, de Fev. 4, 1861, p. 320), Sir William, nevertheless, said only that the shales and limestones of Quebeç and Georgia are *subordinate to the Potsdam*—a formation which Dr. Emmons never claimed, though as we have seen, he consented to its inclusion in the Taconic.

† *Report of Progress from its Commencement to 1863.* Illustrated by 498 wood cuts in the text, and accompanied by an atlas of maps and sections. Montreal, 1863, 8-vo, pp. xxvii x 983.

frequently, the evidences of such an origin, and certainly caused it to appear probable. The anorthosite rock referred to above includes the belt of Labradorite described in 1857, which was made the ground of an "Upper Laurentian" or "Labradorian" division. Of this division nothing is said in the general report of 1863. Speaking of the orthoclase gneiss, the writer says:

"A great portion of the rock is fine grained, and the constituent minerals are arranged in parallel layers; no one constituent predominates in any layer, to the exclusion of others; but even in their subordinate arrangement, there is an observable tendency to parallelism. . . . There is a never-failing constancy in respect to their parallelism which, however, though never absent, is sometimes obscure." . . . Coarse-grained beds of the character designated "granitoid gneiss," "might, on first inspection, be mistaken for igneous, instead of altered sedimentary masses. Upon a careful study of any such mass, however, it will be perceived that this reticulated structure is accompanied by an obscure arrangement of the meshes of the net-work into parallel lines which will be found conformable with the more distinctly banded portion of the strata" (p. 23).

"The greatest masses appear to be formed of the coarse-grained porphyroidal gneiss above described. These rise into the highest ridges and peaks of the orthoclase region, and generally constitute the main body of rock separating one important band of limestone from another. . . . The quartz occasionally presents masses of considerable volume, two of which, nearly pure, occur in the district of the Rouge, a tributary of the Ottawa, one 400, and the other 600 feet thick. The hornblende often forms a massive rock; a band of it in Blythfield has a thickness of 200 feet. Mica, associated with hornblende and with quartz, characterizes great thicknesses of hornblende and micaceous schists."

"Though there does not appear to be any special order in which the masses succeed one another, beds of hornblende rock, and hornblendic schist seem often to be more abundant near the interstratified bands of limestone than elsewhere, and in the same neighborhood, there usually occurs a more frequent repetition of beds of quartzite than in other parts. Near the limestones, pyroxene, which in other parts does not appear to be very abundantly disseminated, is occasionally met with, forming massive beds" (p. 24).

The writer describes the distribution of garnets in the gneiss, and of its passage, in one instance, into garnetiferous quartzite. The masses of limestone are described, sometimes becoming inter-

stratified dolomytes. Serpentine is found associated with both. Pyrallolite, or rensselaerite often accompanies limestone; and pyroxene and hornblende are sometimes found disseminated in grains or crystals. Tremolite forms beds in it. Mica and graphite are both generally present. Pyrites is more abundant. Other minerals are chondrodite, apatite, fluorite and oxides of iron. The gneiss is sometimes greatly contorted, but the beds of associated limestone, even when very thin, are conformable with the beds of gneiss, and parallel with those bands and streaks with which they are marked (p. 27). One instance has been noted "where the limestone of a bed marked with grains of serpentine, appeared to have an uninterrupted connection with rock of an identical character filling up a crack or fault in the gneiss, at right angles to the general direction of the strata" (p. 28).

In a section measured at the High Falls of the Madawaska, a tributary to the Ottawa, here presented as an average section, there are 48 alternations of beds, in a total thickness of 1351 feet. In these, limestones occur six times, giving an aggregate thickness of 46 feet; quartzyte occurs once, in a bed ten feet thick; and "schistose gneiss" occurs five times, giving an aggregate thickness of 116 feet. At a higher position in the series, is said to be a bed of limestone 100 feet thick. At the Chenaux, there is more limestone than gneiss—there being a thickness of over 400 feet, of which not one-fifth is intercalated gneiss; while in Clarendon, similar rocks reveal "a thickness of 4000 feet, about two-thirds of which consists of crystalline limestone" (p. 31).

Another phenomenon of collateral interest, is thus pointed out:

"Notwithstanding the general highly crystalline condition of the Laurentian rocks, beds of an unmistakably *conglomerate* character are occasionally met with among them. . . . On the twenty-fourth lot of the tenth range of Bastard, a bed of conglomerate is interstratified between two beds of limestone. The dip of the strata at the spot is 30°, N. 50° E." The following is a condensed section:

	Feet.	Inches.
7. Limestone, white, coarse........................	6	
6. Limestone, arenaceous, fine, very hard...........		4
5. Sandstone, calcareous, fine.......................		2
4. *Conglomerate,* the matrix a fine grained, quartzose sandstone somewhat calcareous, with white feldspar in grains and pebbles. Pebbles flat, lying on their sides..............................	1	6
3. Quartzite, calcareous-granular, with calcite.......		2
2. Quartzite, coarse, translucent-granular, with feldspar and limestone............................		4
1. Limestone, white, coarse, with graphite and mica..	5	

In Madoc, *conglomerate* occurs again, with calcareous matter; and in a higher position is a ridge "consisting of micaceous schists, beyond which, for 300 yards, ridges of a decided *conglomerate*, with distinctly rounded pebbles, enveloped in a matrix of micaceous schist, alternate with ridges of schist containing few or no pebbles."*

"Still farther north, another band of *conglomerate* occurs, associated with fine grained, soft, micaceo-silicious, feldspathic schist. The matrix of the conglomerate weathers white, and appears to be a dolomite. The pebbles, of which the largest may be six inches in diameter, are chiefly quartz, but there are also, pebbles or masses of feldspar, and a few of calc-spar. The quartz pebbles are for the most part, distinctly rounded, and their colors various, some being internally bluish, some white, and others pinkish. The feldspar is red and white, and the calcspar white. The dip of the rocks appears to be southward of east, but the slope is irregular, and may probably be 35° or 40°" (p. 33.)†

The anorthosite rocks are fully described. Their bedding is very obscure, but they occur in belts conformable with the limestones and the orthoclase gneisses. The hypersthene rock of northern New York, and of the Isle of Skye, are pronounced of the same character. Near Bay Saint Paul, is a mass of titaniferous iron ore in the anorthosite, 90 feet in width, by about 300 feet in length (p. 35.)

The following is a synopsis of a general section across a portion of the Laurentian (p. 45:)

		Feet.
10.	Anorthosite above the Morin limestone (conjectural)	10,000
9.	Orthoclase gneiss (and a band of quartz)	3,400
8.	Proctor's Lake limestone	20
7.	Orthoclase gneiss	1,580
6.	Grenville limestone	750
5.	Orthoclase gneiss	3,500
4.	Great Beaver Lake and Green Lake limestone	2,590
3.	Orthoclase gneiss	4,000
2.	Trembling Lake limestone	1,500
1.	Orthoclase gneiss of Trembling Mountain	5,000
		32,750

*Mr. Macfarlane subsequently describing these conglomerates, says they are "lithologically not unlike some of the Huronian rock." Whereupon, Sir W. E. Logan, in a note replies: "It is not to be inferred from the presence in them of a schistose conglomerate, that therefore, they are Huronian" (*Geology of Canada*, 1866, p. 93.)

†Sir William Logan never omits mention of these conglomerates, when having occasion to furnish a synopsis of the Laurentian. See, for instance, his announcement of organic traces (*Quar. Jour. Geol. Soc. Lond.*, Feb. 1865.)

In reference to the Huronian series, Sir William Logan makes statements from which the following extracts are drawn (p. 90:)

"On Lake Temiscaming, the Laurentian orthoclase gneiss is followed by a slate conglomerate. The finer parts of the rock are dark gray, weathering to dark green; they are of a uniform grain, and, being at the same time, argillaceous and silicious, they present the characters of a hard compact slate. Some parts not so fine in texture, are a hard, dark gray sandstone weathering to a dingy olive green. In both cases, the rock frequently exhibits the character of a compact conglomerate, holding pebbles and bowlders, sometimes a foot in diamater, of the subjacent gneiss, from which they appear to be principally derived."*

Some other conditions of the formation are described as finer textured, penciled in transverse fracture by fine colored lines; another as a "very close grained, compact, dark gray mica slate. When cleavage exists, the planes cut the pebbles in common with the matrix." It is never fit for roofing slates. To this slate conglomerate succeeds a quartzyte, apparently 400 to 500 feet thick.

"On the Sturgeon, Wahnapitæ and Whitefish rivers, there is usually interposed between the Laurentian gneiss and the recognized Huronian rocks, a mass of rather coarse grained greenstone or diorite."

The general section in the region of these three rivers, northeast of lake Huron, and stretching to lake Wahnapitæ—is represented by the following abstract (p. 52):

5. Quartzite, white and greenish, with beds of quartz conglomerate.
4. Slate conglomerate.
3. Limestone, much shattered and disturbed.
2. Slate conglomerate.
1. Silicious strata, fine grained, with greenish quartzite interstratified.

In the region nearer lake Huron, and along the northern shore westward, lies the typical part of the Huronian. As to its relations with the Laurentian, we have from the Canadian geologists, only the following information (p. 55):

"On the coast line, between the Mississagui and the Thessalon rivers, a distance of about 25 miles, the gneiss extends from within

*But it will be remembered that no contact between these so-called conglomerates and the older gneisses had been observed: nor has it to this day. Nor, if such observation had been made, would the circumstance prove these "conglomerates" in immediate chronological succession to the gneiss. Palæozoic limestones were frequently observed resting on gneiss, in the progress of the Canadian survey. The pebbles in this conglomerate may have been derived from the gneiss, and laid down on the gneiss, after the interposition of the events of a geologic age of land history.

about four miles of the former, to within about the same distance of the latter; but, it is very much disturbed by intrusive granite and greenstone, and although there are great exposures of rock, it is very difficult to make out how the stratified portions are related to one another. The gneiss extends to the vicinity of a small stream, about a mile and a half above Les Grandes Sables, and what is supposed to be the lowest Huronian mass of that part, occurs about half a mile above the stream. It consists of a gray quartzite which *abuts against one mass of gneiss and runs under another*, and appears to be much broken by, and entangled among, the intrusive rock; but judging from a transverse measure in one part, its thickness would not be far from 500 feet. Farther west, after passing an exposure of stratified amygdaloidal trap, which would apparently overlie the [this] quartzite, the rocks for about two miles east of the Thessalon, appear to consist of green, fine grained chloritic and epidotic slate ["diabase slate"] alternating with masses that have the aspect of trap."

The following is an abstract of the general section in this region (pp. 55–7):

		Feet.
13.	White quartzite	400
12.	Yellowish chert and impure limestone	200
11.	White quartzite, frequently vitreous	1,500
10.	Yellowish chert, with thin and very regular beds	400
9.	White quartzite, frequently vitreous	2,970
8.	Red jasper conglomerates. Sometimes fine white quartzite. Greenstones intercalated	2,150
7.	Red quartzite with interstratified greenstones	2,300
6.	Slate conglomerate with interstratified greenstones	3,000
5.	Limestone, compact, green, drab or gray, thin bedded	300
4.	Slate conglomerate [as previously described]	1,280
3.	White quartzite, sometimes pebbly	1,000
2.	Chloritic and epidotic slates [probably eruptive]	2,000
1.	Gray quartzite, thickness doubtful	500
		18,000

It will be desirable to contemplate the above section separately from the section of "Huronian" rocks reported from the north shore of lake Superior. It is quite possible that the two sections relate to rocks belonging to different geological ages.

"On lake Superior, the Laurentian gneiss is succeeded by slates generally of a dark green without, and often of dark gray in fresh fracture, which at the base appear occasionally to be interstratified with beds of a feldspathic character, of the reddish color belonging to the subjacent gneiss. Sometimes these beds are a combination

of feldspar and quartz, occasionally with the addition of hornblende and, in some of the beds, the hornblende predominating, gives them a general green color. Some of the beds have the character of diorite; others, that of mica slate, and a few present that of quartzite" (p. 52).

These seem to be identical with the lowest rocks of the iron-bearing series of Vermilion lake, a part of Lawson's Keewatin. They exhibit the well-known transition from Laurentian gneiss to crystalline schists. The mica schist is "nascent."

"Rising in the series, the dark green slates become interstratified with layers holding a sufficient number of pebbles of different kinds, to constitute *conglomerates*. The pebbles appear to be all derived from altered rocks; they greatly vary in size in different places, and occasionally measure a foot in diameter. Where the *slate conglomerates* have been worn by the action of water, the pebbles are generally worn down equally with the rest of the surface; and though a very distinct picture of them is presented on such a surface, where the water or weather appears to have had an influence in bringing out a well defined contrast in colors between the pebbles and the slate, at the same time producing a contrast between parallel bands of the slate on the terminal edges of the laminæ, it yet often happens, unless the pebbles are of white quartz, that they are very obscurely distinguishable on fracturing the rock — both the pebbles and the matrix having a gray color, and showing very little apparent difference in mineral character. On some of these pictured surfaces, small opaque, white feldspathic crystals occasionally spot the whole surface of the rock — the pebbles equally with the slaty matrix. The rock has nowhere on the lake been observed to display true slaty cleavage, independent of the bedding; but it often exhibits a jointed structure, and the divisional planes cut through the pebbles without the smallest deflection."* (pp. 52 and 53).

It is impossible to identify this description with the description of the Huronian rocks north of lake Huron. There are some circumstances which readily explain the course taken by the Canadian geologists, but the identification made as early as 1848, has perpetuated misconceptions, and bred unintelligible confusion. I have some confidence that we may be near the solution of the puzzle.

* The whole of the above description applies exactly to the lower part of the "Ogishke Conglomerate," on the shores of Ogishke Muncie or Kingfisher lake, in Minnesota, eighty miles west of Thunder bay. I shall return in the sequel, to a discussion of this identification. The stratigraphical position of the "Ogishke Conglomerate" has been in doubt; but if this parallelism is correct, it belongs near the bottom of the Vermilion lake iron-bearing schists.

The same basal slaty conglomerate occurs at other points along the north shore.

"A considerable thickness of these conglomerate or pebbly slates, is exposed at the mouth of the river Doré, near Gros Cap, about five miles above the mouth of the Michipicoten river. The strike of the rock is very regular, being about east and west, while the dip is highly inclined, the beds being not more than from ten to fifteen degrees from a vertical attitude; but the slope is for part of the distance, to the north, and for the remainder, to the south; there is not, however, supposed to be any repetition of the measures, which are given in descending order" (p. 53).

		Feet.
21.	Green slate rock, with a few scattered pebbles through some parts of it, in other parts conglomeratic; the sedimentary layers not distinctly marked; rock with a jointed structure; joints cutting straight through the pebbles	40
20.	Green pebbly slate; edges of laminæ well marked, producing a ribboned appearance; pebbles chiefly gneiss, granite or syenite	300
19.	Green slate rock similar to 20 and 21	550
18.	Green pebbly slate	170
17.	Measures covered by sand	90
16.	Green slaty conglomerate, with large pebbles of igneous or altered rock	15
15.	Green slate rock with many pebbles	30
14.	Green slate with finer pebbles	40
13.	Green slate rock, with scattered, large pebbles	10
12.	Green slate rock, like 13	130
11.	Green slate conglomerate, with boulders sometimes a foot in diameter, in a slaty matrix	5
10.	Measures concealed by sand	30
9.	Green slate rock with many pebbles	30
8.	Green slate rock with pebbles	30
7.	Measures concealed by sand	20
6.	Green slate rock, very pebbly, sedimentary layers finely waved, water worn surface much pitted	30
5.	Green slate rock, bedding very even, appears to be somewhat talcose toward the top	20
4.	Green slate rock like 5	15
3.	Green slate rock with even bedding, slightly unctuous and talcoid in several of the divisions	20
2.	Green slate rock, a few scattered pebbles in parts, flattened in direction of the strata	90
1.	Green slate rock with large pebbles and small boulders of granite or gneiss, quartz and a chert-like stone (p. 54)	35
		1,700

The foregoing section is almost a continuous "slate conglomerate," or pebbly slate, and but for the so-called "talcose" matter, might hastily be identified with the slate conglomerate of the Thessalon valley. But, as will be shown, it is a different slate. The descriptions again apply to the Ogishke conglomerate. In Minnesota, this conglomerate is only one member of the iron-bearing series. In accordance with that fact, Sir William Logan adds:

"At the Doré, a much larger amount of the slate formation than is here given comes in behind the preceding section; but it was so covered with trees and moss, at the time of the examination, that it was found impossible to follow out the details. Toward the lower part, it *assumes more the character of the gneiss* which usually succeeds it, and becomes *interstratified* with reddish-yellow feldspathic layers; but sufficient data have not yet been ascertained to determine what may be the total thickness of the slate rock in this part, though it must probably attain several thousand feet" (p. 54).

Other localities on lake Superior where slate conglomerates and jasper conglomerates occupy a similar position, are between the Goulais river and Batchewahnung bay. The same seem to extend along the shore of the Michipicoten river, on each side, eight or nine miles. It occurs also, a little farther west on the coast, and again about five miles south of Otter Head (p. 63).

"Another locality is Thunder bay, where they occupy the coast for a distance of ten miles, immediately below the mouth of the Kaministiquia river, on the north side, leaning in a narrow strip against the gneiss of the lower series. It is not improbable that they may present a narrow belt in the valley of the Kaministiquia They occupy the coast for about seven miles on each side of the New Pic river; while an interval from this to a point two miles beyond the Old Pic river, including the coast of Peninsula Bay and Harbor, and Pic island, is composed of trap. Beyond this, the chloritic slates occupy about fifteen miles of the coast, extending to the neighborhood of the deep cove which receives the Pike river" (p. 64).

A characteristic feature of the Keewatin iron-bearing series is indicated in the description of the junction of these rocks with the gneiss on the Kaministiquia river, in the vicinity of the Grand Falls:

"At the lower end of the portage, where the series makes its appearance, the rock resembles a massive syenite, in some parts red, and in others, whitish, but is probably a hornblendic gneiss in which the lamellar arrangement of the constituent minerals is

obscure, as the rock gradually passes into such a gneiss. Resting on it *conformably*, there occurs a series of dark greenish blue, or greenish black slates, the one rock *passing almost imperceptibly into the other*. . . At each rapid part of the river above the Grand Falls, there is a greater or less development of these rocks, most frequently presenting the more distinctly stratified part of the gneiss. The best exposure of the slate is at the Three Discharges, about four miles above the Grand Falls, where the rocks are observed to pass from the gneiss to the slate." The vertical thickness at this place is about 2,300 feet.

"Toward the bottom, near the junction with the gneiss, the slates are of a bluish and occasionally of a brownish color. They are intersected by numerous parallel joints which divide the mass into rhomboidal forms of singular regularity. The middle and upper portions of the section are usually of a pistachio green, resembling the green of epidote, and frequently in part present a jaspery character. They are hard and compact, usually with a conchoidal, but sometimes with a splintery fracture. The divisional planes are frequently covered with mica, and in such cases, the rock may almost be termed a mica slate" (p. 65). Similar rocks continue as far as Dog lake.

The foregoing description applies perfectly to the passage from the iron-bearing formation to the gneisses, as observed in a hundred places in northeastern Minnesota. No structural unconformity exists, as a fact of present observation. It is not intended to assert, however, that it never existed.

The schists observed along the north shore of lake Huron, in which the Bruce and Wellington and Wallace mines were worked, constitute Logan's "Lower Copper-bearing series." As these were identified with the series of slates just described, they were also made to represent the Lower Copper-bearing series. Neither series could be identified with the copper rocks of the south shore of lake Superior. But as those rocks were observed on the north shore at a higher stratigraphic level, they were demoninated by Logan the "Upper Copper-bearing rocks." But in thus fixing parallelisms, he strangely overlooked the importance of a series between the proper Cupriferous rocks above and the pseudo-Cupriferous rocks below. These were the real Lower Copper-bearing rocks, though Logan joined them to the Upper, or south shore Cupriferous. His treatment of the so-called "Upper Cupriferous rocks" will appear from a few extracts.

"The Huronian formation of Lake Superior [the real iron-bearing series] is *unconformably* overlaid by a second series of copper-

bearing rocks, which may be conveniently divided into two groups. Of these the lower consists of bluish slates or shales interstratified with sandstones and beds of columnar trap; and the upper, of a succession of sandstones, limestones, indurated marls and conglomerates, also interstratified with trap which is often amygdaloidal" (p. 67).

The following is a characterization of the lower group of the Upper Copper-bearing series, (p. 67):

"The base of the formation where seen in Thunder Bay, in contact with the subjacent green slates or slate conglomerates, presents conglomerate beds probably of no great thickness, composed chiefly of quartz pebbles, with a few of red jasper, and some of greenish, chloritic slate, in a greenish, arenaceous matrix, consisting of the same materials in a finer condition. These are followed by a set of very regular, even layers of chert, sometimes approaching a chalcedony, varying in color from nearly white, through different shades of gray to black, and in thickness, from less than half an inch to six inches, and even a foot. These are separated from one another by thin layers of dark gray dolomite, weathering rusty-red and present a striking ribbon-like appearance. Occasionally, thicker beds of dolomite occur, sometimes highly crystalline, separating aggregated bands of the ribbon-like strata; and these dolomitic beds, as well as the chert bands, are sometimes interstratified with argillaceous layers" (p. 67).

"In the vicinity of disturbed parts, the chert sometimes passes into chalcedony and agate, and small cracks are filled with what appears to be anthracite. Some of the chert bands appear to be made up of a multitude of minute, irregular, closely aggregated, sub-globular bodies, floating as it were, in the silicious matrix. Anthracite seems to be present in the centre of some of these, leading to the supposition that the color of the black chert, even where these shapes are not detected, may be owing to the presence of carbon. In some parts of these oölitic chert layers, small blood-red jasper spots occasionally become interstratified with the black. . . .

"Higher in the formation, argillaceous slates become interstratified with argillaceous sandstones in such an ealterd condition that it is often difficult, at first sight, to say whether the latter may not be trap layers. . . In some parts of the vertical thickness, calcareous layers are occasionally interstratified among the slates, but few of them are pure enough to be entitled to the appellation of limestones. . . "On the Kaministiquia, the lowest part of the formation occurs near Grand Falls. Its immediate junction with

the rock on which it rests is concealed from view. . . The argillaceous strata visibly reach to within a short distance of the pond [in which the junction is supposed to occur] (p. 68).

"The general color of the rock is here black, weathering to a rusty brown. Some of the beds being soft and shaly, are easily decomposed by atmospheric influences, while the mass is, for the most part, a hard argillaceous slate. The whole formation appears to be more or less calcareous, and among the lower members, thin beds of magnesian limestone occur, sometimes alternating with thin beds of black chert" (p 68–9).

"In Thunder bay, and on the coast above it, trap bands, conformable with the stratification, are interstratified in several parts of the formation, but they occur in greatest thickness toward the bottom, not far above the chert-beds, and at the summit, overlying the whole of the mass. . . In all cases, the trap presents a very striking sub-columnar structure at right-angles to the plane of the stratification; and the crowning overflow gives a peculiar aspect to the whole region occupied by the formation to which it belongs. The overflow is from 200 to 300 feet thick, and the whole of the associated rocks, to the base of the formation, may possess a volume of between 1,500 and 2,000 feet." (pp. 69, 70).

The foregoing is a good description of the black slates and the slate-conglomerate of the so-called Huronian series north of lake Huron. In the latter region, columnar trap (or gabbro) does not constitute a persistent "crowning overflow", as far as the descriptions given by the survey indicate, but interbedded traps are present, and the lithological characters of the formation—the black shale, the cherty and flinty layers, the oölitic structure, the even beds, the proximate horizontality—and no other known formation about lake Superior presents any close resemblance to the Huronian strata. These black slates of Thunder bay, moreover, are now known to extend westward into Minnesota, and to overlie unconformably a mass of vertical, sub-crystalline schists in the same manner as at Thunder bay.

As to the upper group of the Upper Copper-bearing series, little needs to be said here, as this is the well known Cupriferous series of the south shore, consisting chiefly of intercalated beds of sandstone, conglomerate and trap, with occasional beds of limestone, and attaining an aggregate thickness of 6,000 to 10,000 feet. The trap is often amygdaloidal, and native copper occurs in irregular grains and strings and masses up to ten pounds in weight. Sir William Logan's discussion of this formation does not possess theoretical significance.

In an appendix to the report of 1863, Sir William Logan states that "the Taconic system of Emmons, which he supposed to be a distinct series of rocks more ancient than the Potsdam, appears to consist, for the greater part at least, of the strata of the Potsdam and Quebec groups. The Upper Copper-bearing rocks of lake Superior are regarded as occupying the position of the Quebec group, to which they bear some resemblance in lithological and mineralogical characters. They may, perhaps, include the Potsdam group."* [Compare the views of Foster and Whitney.]

The following is a summary of Sir William Logan's successive views on the classification of the Azoic rocks of Canada:

<table>
<tr><th colspan="5">DIVISIONS OF ARCHÆAN ROCKS RECOGNIZED BY LOGAN.</th><th>PUBLICATION.</th></tr>
<tr><td colspan="5">Metamorphic Series.</td><td>1845.</td></tr>
<tr><td colspan="2">Lower Group.</td><td colspan="3">Upper Group (Lake Sup).</td><td>1846.</td></tr>
<tr><td colspan="2">Gneiss, Mica slate.</td><td colspan="3">Quartz rock, etc.</td><td>1847.</td></tr>
<tr><td colspan="5">Granitic or Metamorphic Group.</td><td>(1848) 1850.</td></tr>
<tr><td colspan="5">Metamorphic or Gneissoid Group.</td><td>(1849) 1850.</td></tr>
<tr><td colspan="5">Metamorphic Group.</td><td>1851.</td></tr>
<tr><td colspan="2">Gneiss, etc.</td><td colspan="3">Cambrian.</td><td>(1851) 1852.</td></tr>
<tr><td colspan="5">Laurentian Series.</td><td>(1852) 1854.</td></tr>
<tr><td colspan="2">Laurentian Formation.</td><td colspan="3">Huronian Series (Murray).</td><td>(1853-7) 1857.</td></tr>
<tr><td>Laurentian</td><td>Upper Laurentian. or Labradorian.</td><td colspan="3">Huronian.</td><td>1857.</td></tr>
<tr><td colspan="2">Laurentian.</td><td>Huronian. (Lower Copper bearing rocks.)</td><td colspan="2">Upper Copper-bearing rocks.</td><td>(1863).</td></tr>
<tr><td colspan="2">Laurentian Series.</td><td>Huronian Series.</td><td colspan="2">Upper Copper-bearing rocks. (Quebec group)</td><td rowspan="2">1866.</td></tr>
<tr><td colspan="2"></td><td></td><td>Lower group</td><td>Upper group</td></tr>
</table>

NOTE.—Dates of presentation of reports are placed in parentheses.

One of the important features of the volume on the Geology of Canada, 1863, was the introduction of the "Quebec Group," supposed to be a group of strata occupying a position between the characteristic part of the Calciferous and the Hudson River shales, and specially investigated in the vicinity of Quebec. Sir William Logan was so good a physical geologist that when he had given his sanction to the proposal, a strong predisposition was given to American opinion. Thus the Quebec group had the sanction of James Hall, E. Billings and T. S. Hunt, and found admission to the second edition of Dana's "Manual of Geology." We have seen, however, what misgivings on the subject were entertained by professor Hall, and how he permitted his respect for Sir William Logan to compromise his own palæontological convictions. The "Group" remained a stumbling-block and an enigma in American geology until, failing in prestige during the last decade, it received its final *coup de grace* at the hands of the Survey itself, in 1889.†

*Geology of Canada. 1863, p. 934.

†Second Report on the Geology of a portion of the Province of Quebec. R. W. Ells. *Geol. Sur. Canada, Annual Report*. 1887-88. Montreal 1889.

It would be profitless to pursue the history of an opinion which has already lost its hold on credence, even if were the purpose of the present memoir to deal with discussions exclusively palæontological. But the rocks have been, in some regions, so confounded with those of the so-styled Taconic, that the investigation of the latter involves a review of opinion on the former. For the convenience of the student, therefore, the titles of the principal papers bearing on the discussion, are here appended*

*1861. Logan, Sir W. E.
In "Correspondence of Joachim Barrande, Sir William Logan and James Hall, on the Taconic System, and the Age of the Fossils found in the Rock of northern New England and the Quebec Group of Rocks." *Amer. Jour. Sci.* II, xxxi. 210-226.

1862. Logan, W. E.
Determination of Age of Quebec Rocks. *Amer. Jour. Sci.*, II, xxxiii, 105-6.

1862. Logan, W. E.
Considerations relating to the Quebec Group and the Upper Copper-bearing Rocks of Lake Superior (Read before Montreal Nat. Hist. Soc.), *Amer. Jour. Sci.*, II, xxxiii. 320-327.

1863. Logan, W. E.
The Quebec Group. *Geology of Canada*, 1863, pp. 225-397.

1863. Logan, Sir W. E.
Letter addressed to Mr. Joachim Barrande, on the Quebec Group at Point Lévis. Montreal, pp. 1-14. Reprinted, *Amer. Jour. Sci.*, II, xxxvi, 366-377.

1866. Logan. Sir W. E.
The Quebec Group and its Divisions. *Canada Report*. 1863-6, pp. 4-6.

1866. Richardson, James.
Divisions of the Quebec Group. *Canad. Rep.*, 1863-6, pp. 29-34.

1870. Richardson, James.
Report on the South Shore below Quebec [Rocks of the Quebec Group]. *Canad. Rep.*, 1866-1869, pp. 119-149.

1873. Selwyn, A. R. C.
Note of a Preliminary Geological Reconnoissance from Lake Superior by the English and Winnipeg rivers to Fort Garry [Compared with Quebec]. *Canad. Rep.* for 1872-3, pp. 8-18.

1879. Selwyn, A. R. C.
Report of Observations on the Stratigraphy of the Quebec Group and the Older Crystalline Rocks of Canada. *Canad. Rep.*, 1877-8, A, pp. 1-15.

1883. Adams, Frank D.
Notes on the Microscopic Structure of some Rocks of the Quebec Group. *Canad. Rep.*, 1880-82, A, pp. 8-23.

1887. Ells, R. W.
Report on the Geology of a portion of the Eastern Townships of Quebec. *Canad. Rep.* 2d Ser. Vol. II, 1866, J. pp. 1-70.

1888. Ells, R. W.
Second Report on the Geology of a portion of the Province of Quebec. *Canad. Rep.* 1887-8, Vol. III, Pt. 1. K, pp. 1-120.

1890. Ells, R. W.
The Stratigraphy of the Quebec Group *Bull. Geol. Soc. Amer.*, I. 453-468.

1890. Brainerd, Ezra and Henry M. Seely.
The Calciferous Formation in the Champlain Valley. With a Supplement on the Fort Cassin Rocks and their Fauna, By R. P. Whitfield. *Bull. Geol. Soc. Amer.*, I, 501-516.

1890. Walcott, C. D.
A review of Dr. R. W. Ells' Second Report on the Geology of a Portion of the Province of Quebec, with Additional Notes on the "Quebec Group." [History of Views] *Amer. Jour. Sci.*, III., xxxix, 101-115.

1890. Hunt, T. Sterry.
The Geological History of the Quebec Group. *American Geologist*, Vol. iv, p. 212.

See, also, the references on the Taconic System, many of which bear on the Quebec Group.

JOSIAH D. WHITNEY.

1847. Josiah D. Whitney and Joseph W. Foster were assistants, in 1847, of Dr. C. T. Jackson in his survey of the "mineral lands" of lake Superior; and Mr. Whitney continued in the same capacity in 1848. In 1849 and 1850, Messrs. Foster and Whitney succeeded Dr. Jackson, and their Annual Report is dated Boston, Nov. 5, 1849. Mr. Whitney's observations in 1847, were restricted to the copper-bearing rocks, mostly of the Ontonagon district, and he had no occasion to introduce general views in his report; but a part of Mr. Foster's notes relate to a traverse from lake Superior over the Menominee region, to Green bay.* Mr. Whitney does not appear to have transmitted to Dr. Jackson, anything except barometric observations as the result of work in 1848 (*op. cit.*, pp. 644-646).

1849. In their report of 1849, Messrs. Foster and Whitney say: Experience "has demonstrated that the veins of copper and, its ores in the sandstone and conglomerate are not to be relied on, and that when worked even to an inconsiderable depth, they give out. . . All the productive lodes are confined to the ranges of trap. . . The associated sandstone and conglomerate belong to the Silurian system, and rest at the base of all the fossiliferous rocks" (p. 607.)† Accompanying this report are four geological maps: 1. Ile Royale; 2. Keweenaw Point; 3. The district between Keweenaw Bay and Chocolate River; 4. The district between Portage Lake and Montreal River. On the 3d and 4th of these Maps, the term "Azoic" is introduced. The 4th Map was transmitted to the Secretary of the Interior by a letter dated July 25th, 1849. The date of transmittal of the other is not known, but probably, the same month. On the 3d Map, the explanatory legend presents the following arrangement:

Aqueous,	Base of the Silurian System,	Sandstone.
Metamorphic,	Azoic System,	Quartz. Saccharoidal limestone Schistose Rocks.

*The Report is found on pp. 773-784 of that chaos of literary, scientific and statistical matter called Jackson's Geological Report, occupying pages 371-801 of "*Annual Message and Documents*," 1849-50, Part III—except pages 605-624, including four maps, occupied by Foster and Whitney's report for 1849, which is interjected into the midst of Jackson's report.

†Dr. Jackson, (*op. cit.* p. 399), says "Anterior to my researches, the red sandstones of Lake Superior were supposed to be the "old red," and subsequently the opinion that they belonged to the Potsdam, N. Y., series, gained ground; but, from the facts that the mineral composition, associations and contents were identical with the sandstones of Nova Scotia, Connecticut, Massachusetts and New Jersey, and that the disturbing agency which moved them was in the same direction and produced similar, if not identical results, I was disposed to regard those rocks as of the same age, or as of the New Red sandstone series. This idea has been confirmed."

Igneous Formation,	More recent than the Azoic, but older than the Silurian,	Trappean Rocks. Granite. Basalt.

The legend on the 4th Map is as follows:

Aqueous Formation,	Lower Silurian System.	Lower Magnesian Limestone. Sandstone. Conglomerate.
Metamorphic,	Azoic System,	Schistose Rocks.
Igneous,	Contemporaneous with Silurian,	Trap. Jasper and Quartzose Porphyry.
	More recent than Azoic,	Granite.

1850. The first part of the final report, relating to the "Copper Lands," was transmitted April 15, 1850.* In the IVth chapter, the authors, treating of "Stratified and Sedimentary rocks," comprise them under three general divisions:

III. Compact or Lower Magnesian Limestones. 3. Birdseye and Black river limestone; 2. Chazy limestone; 1. Calciferous sandstone.

II. Inferior Sandstone. Potsdam Sandstone.

I. Conglomerate. Not strictly a sedimentary rock, but a volcanic tuff.

Speaking more particularly of the conglomerates, the authors state concerning the pebbles: "Their surfaces do not present that smooth, polished appearance which results from the attrition of water,† in fact, a close observer can readily distinguish between those which have been recently detached from the rock and those which have been for a time exposed to the recent action of the surf. The conglomerate appears to have been formed too rapidly to suppose that the masses were detached and rounded by the action of waves and currents, and deposited with silt and sand on the floor of the ancient ocean; for while the contemporaneous sandstone remote from the line of volcanic foci, does not exceed three hundred or four hundred feet in thickness, the united thickness of the conglomerate bands, in the vicinity of the trappean range on Keweenaw Point, exceeds five thousand feet. As we recede for a few miles from the line of the volcanic fissure, these amygdaloidal pebbles disappear, and are replaced by arenaceous and argillaceous particles. We are therefore disposed to adopt the theory as to the origin of such masses first suggested by Von Buch: 'When basaltic islands and trachytic rocks rise in fissures, friction of the elevated rock

Report on the Geology and Topography of a Portion of the Lake Superior Land District in the State of Michigan. By J. W. Foster and J. D. Whitney, United States Geologists. In two parts. Part I, Copper Lands. Washington, 1850, 8vo, pp. 224, with a Map and xii Plates. (Being *Ex. Doc.* No. 69, House of Representatives, 31st Cong, 1st Sess.)

†The "attrition" which rounds shore pebbles is not "attrition of water". Perhaps the authors mean attrition *in* water.

against the walls of the fissures, causes the elevated rock to be enclosed by conglomerates composed of its own matter. The granites composing the sandstones of many formations have been separated rather by friction against the erupted volcanic rock than destroyed by the erosive force of a neighboring sea. The existence of these friction conglomerates, which are met with in enormous masses in both hemispheres, testifies to the intensity of the force with which the erupted rocks have been propelled from the interior through the earth's crust. The detritus has suddenly been taken up by the waters, which have then deposited it in the strata which it still covers'.* Those pebbles having a highly vesicular structure may have been ejected through the fissures in the form of scoriæ while in a plastic state, and have received their rounded shape from having been projected through water—on the same principles as melted lead when dropped from an elevation assumes a globular form '.†

On page 112, in a note, the authors cite similar conglomerates of eruptive origin, in the Hawaiian and Fiji islands, as described in the report by professor Dana, on the Geology of the Exploring Expedition.

In speaking of the sandstone, they do not, like Houghton, discriminate between that which is interbedded with conglomerate layers, and that which overlies both, though they recognize, as Houghton did, the synclinal arrangement of the beds forming the lake basin, and give a theoretical diagram illustrating it. They say: "During the deposition of the sandstone, numerous sheets of trap were ejected and flowed like lava streams, and the igneous and aqueous products were so intermingled as to present the appearance of having been derived from a common origin." (p. 110.) The general discussion, however, relates to that which Houghton had denominated "Lower or Rèd Sandstone."

The method of geologic action which gave origin to the Cupriferous formation is conceived by the authors as follows: The entire region was the bed of an ocean of heated waters, and volcanic paroxysms were frequent. Numerous fissures through the crust of the earth resulted. "Along the lines of these fissures existed numerous volcanic vents, like those observed at this day in Peru, Granada and Java, which were characterized by periods of activity and repose. From these vents were poured forth numerous sheets of trap, which flowed over the sheets of sand and clays then in progress of accumulation. During the throes and convulsions of

*Geognostische Briefe, S. 75-82.

†Report on Copper Lands, pp. 99, 100.

the mass, portions of rock would become detached, and rounded simply by the effects of attrition, and jets of melted matter be projected as volcanic bombs through the air or water, which on cooling would assume spheroidal forms, while other portions of the rock, in a state of mechanical division, would be ejected in the form of ashes and sand, which mingling with the water, would be deposited, as the oscillations subsided, among the sand and pebbles at the bottom of the sea. During the whole of this period of volcanic activity, the sands which now form the base of the Silurian system were in progress of accumulation, and became mingled with these igneous products" (p. 120). "Thus, alternating bands of igneous and aqueous rocks were formed", and thus, unlike the theory of Dr. Houghton, which regarded the trap sheets as dykes, our authors contemplate them as overflows.

1851. The second part of Foster and Whitney's report on the Mineral Lands of Lake Superior* was transmitted to the secretary of the Senate, November 20, 1851. It is a comprehensive, thorough and scientific presentation and discussion of the general and economic geology of the region embraced — with the exception of matters treated in Part I. It is probably the most meritorious production to that time issued under the auspices of the general government. The lithographed engravings are superior, but the wood-cuts are obscure, and the typography and paper cheap and unworthy. This volume has become celebrated as the one in which the "Azoic System" was established in America.

In the preliminary chapter, a general classification of the rocks of the district is given, of which the following is the lower part :†

Aqueous.	Silurian System.	Potdsam Sandstone,‡ etc.	
Metamorphic.	Azoic System.	Beds of Quartz and Saccharoidal Marble. Chloritic, Talcose and Argillaceous Slates Gneiss, Mica and Hornblende Slate.	
Igneous.	Of various ages.	Trappean volcanic rocks.	Masses of Specular and Magnetic Oxide Iron. Hornblende and Serpentine rocks. Basalt, Amygdaloid, Greenstone or Dolerite Porphyry.
		Plutonic rocks.	Feldspar and Quartz rock. Syenite. Granite.

"Below all the fossiliferous groups of this region" say the authors, "there is a class of rocks consisting of various crystalline

* *Report on the Geology of the Lake Superior Land District.* By J. W. Foster and J. D. Whitney, United States Geologists. Part II, The Iron Region, together with the General Geology, March 13, 1851: Ordered to be printed, Washington, 1851 [8-vo., pp. 406, 36 plates of illustrations, and a geological map of the upper Peninsula of Michigan and of the north shore of lake Superior from Sturgeon bay eastward.]

† It will be remembered that in all the stratigraphic tables of the present memoir, the older rocks stand below. This is an inversion of the arrangement adopted by Foster and Whitney, and most of the earlier writers.

‡ The age of the Potsdam sandstone was discussed by the authors in *Proc. Amer. Assoc.*, Cincinnati meeting, 1851, (pp. 22-38).

schists, beds of quartz, and saccharoidal marble, more or less metamorphosed, which we denominate the Azoic system. This term was first applied by Murchison and De Verneuil* to designate those crystalline masses which preceded the Palæozoic strata. In it, they include not only gneiss, but the granitic and plutonic rocks by which it has been invaded. We adopt the term but limit its signification to those rocks which were detrital in their origin, and which were supposed to have been formed before the dawn of organized existence.†

Obviously, there is a degree of indefiniteness about this definition: 1st. Remains of organization may be found in rocks which "preceded the Palæozoic" as understood by Murchison: 2d. Not only gneiss but granite and syenite may yet be proven of detrital origin. Thus the base of the Palæozoic may be lowered either by the discovery of fossiliferous rocks between the Potsdam and the top of the Azoic as known to Foster and Whitney, or by the discovery of fossils within the Azoic rocks as thus known; and the base of the Azoic may be raised by the demonstration of the original igneous condition of the gneisses, or lowered by the demonstration of the original sedimentary condition of the granitoid masses. These, however, are only practical difficulties in the application of the conception of Foster and Whitney. The conception as above defined is clearly delimited and rational. By a reasonable application of the conception, the Azoic system would always embrace the strata beneath the oldest at any time found to be fossiliferous‡ and above the rocks at any time held to be igneous in origin. This was very nearly Emmons' first conception of the Taconic, nine years earlier; but he recognized the Potsdam sandstone as the base of the Silurian system, and only by provisional inference, the base of the Palæozoic series so that when strata older than the Potsdam were found fossiliferous, he changed his view in reference to the azoic character of the Taconic, and thereafter insisted that it was a zoic system.

"Most of these rocks [of the Azoic system,] the authors state, "appear to have been of detrital origin, but greatly transformed by long exposure to heat. They are sub-crystalline or compact in

* *The Geology of Russia in Europe and the Ural Mountains*, vol. i, p. 10, 1845,. See also, *Proc. Geol. Soc. Lond.*, vol. iv, p. 602, 1845.

†Foster and Whitney; *Rep.*, p. 3.

‡Mr. Whitney has indicated the possibility that the upper limit of the Azoic might have to be placed lower than the base of the Potsdam sandstone. "If we find in this country, a series of fossiliferous beds below those at present recognized, and whose organic contents cannot be considered as being of Lower Silurian type. let us give them a new name which shall not involve us in any Cambrian controversies." (*Amer. Jour. Sci.*, II, xxiii, p. 314).

their structure, and rarely present unequivocal signs of stratification. They exhibit the most violent dislocations; in one place the beds are vertical, in another, reversed, and in another, present a succession of folded axes. Intermingled with them is a class of rocks whose igneous origin cannot be doubted, and to whose presence, the metamorphism so characteristic of this series, is in some measure to be ascribed. They consist of varying proportions of hornblende and feldspar, forming traps and basalts, or, where magnesia abounds, pass into serpentine rocks. They appear in some instances to have been protruded through the pre-existing strata, in tne form of dikes or elvans, in others, to have flowed in broad lava streams over the ancient surface; and in others, to have risen up through some wide-spreading, expanding fissure, forming axes of elevation" (p. 8).

"Many eminent geologists maintain that the lowest stratified rocks are but portions of the Silurian or Cambrian system; and that from long continued exposure to heat the lines of stratification have become obscure, and all traces of organic remains obliterated. Our investigations in this district have led us to a different conclusion. If the Potsdam sandstone rests at the base of the Palæozic series; if from that epoch we are to date the dawn of animal creation, there is in this district a class of obscurely stratified rocks interposed between the Silurian system and the granite—rocks distinct in character, unconformable in dip, and destitute of organic remains" (p. 10).

The authors quote from the early reports of "Mr. Logan, the distinguished Provincial geologist of Canada, for the purpose of stating that the two-fold division of these rocks, described by Mr. Logan* has not been observed on the southern shore.

In reference to the blending of igneous and sedimentary characters in the Azoic rocks of the south shore, the authors quote from de la Beche a passage which, though it possesses only the authority of an individual, needs to be borne in mind in the more recent attempts to interpret the rocks in question, whether on the south or the north shore. This is the passage:

"There is so intimate a mixture of compact and schistose trappean rocks with the argillaceous slates [of Bossiney, Cornwall] that the whole may be regarded as one system, the two kinds of trappean rocks having been probably erupted, one in a state of igneous fusion, and the other in that of an ash, during the time that

Report of Progress, 1846-7, p. 10. It is clear that the upper division here indicated in the metamorphic rocks is what was afterward denominated *Animike*. But we shall return to this point. It is also apparent that this division, if not entirely wanting on the southern shore, is very inconspicuously developed.

the mud now forming slates, was deposited; the mixture being irregular from the irregular action of the respective causes which produced them, so that, as one may have been derived from igneous action, and the other from the ordinary abrasion of pre-existing solid rocks, they were geologically contemporaneous."

Some further remarks by the authors relate specifically to the rocks on the south shore of lake Superior. "Many of the igneous rocks of this region form neither long lines of dykes nor axes of elevation, but broad sheets, bearing the same relation to the slates that the trappean bands of Keweenaw Point do to the conglomerates. Many of the slates appear to be composed of pulverulent greenstone, as though they might originally have been ejected as an ash, and subsequently deposited as a sediment, and pass by imperceptible gradations from a highly fissile, to a highly compact slate." Some of these phenomena are compared with sub-oceanic salses,"pouring forth streams of pulverulent material to be mingled with ordinary fragmental deposits.

Messrs. Foster and Whitney, in concluding their account of the general geology of the Azoic system, seek to strengthen its establishment by pointing out the existence of a similar series of rocks in other states—in Minnesota, Arkansas, Missouri, New York, Pennsylvania and Virginia. They refer to the evidence supplied by the brothers Rogers, that the series of obscurely stratified rocks known as the gneissoid series, flank the Appalachian chain on the east throughout its entire extent. Turning to the Old World, they cite the well known witnesses to the existence of similar azoic rocks in Scandinavia, Great Britian and Bohemia (pp. 33, 34.)

As to the origin of the mass of magnetic oxides of iron, having shown that they occur in beds instead of true veins, they consider the evidences of an igneous and of a metamorphic origin, and conclude: "On the whole, we are disposed to regard the specular and magnetic oxides of iron as a purely igneous product, in some instances poured out, but in others sublimed, from the interior of the earth. . . Where these ores occur in a state of almost absolute purity, in the form of vast irregular masses, occupying pre-existing depressions; or where the incumbent strata are metamorphosed and folded over them; or where they are traversed by long lines of ferruginous matter in the form of dykes—there can be little doubt that these ores have risen up in a plastic state from below.

"Where they are found impregnating metamorphic products, such as jasper, hornstone or chert, quartz, chlorite and talc slate, not only interposed between the laminæ, but intimately incorpora-

ted with the mass, giving it a banded structure, we regard it as the result of sublimation from the interior."

"When they are included in metamorphic strata, in the form of beds of variable width, with a conformable range and dip, and with minute particles of the associated rock mechanically mixed with the ore, we are disposed to regard them as the result of aqueous deposition, although the materials may have been derived from the ruins of purely igneous products" (p. 68.)

In *1857*, Sir William Logan and the Canadian geologists having recognized two distinct systems beneath the Potsdam sandstone, Mr. Whitney returned to the defence of the systemic unity of the sub-Silurian rocks, and of the system which he and Mr. Foster had proposed to receive them.* Mr. Whitney thinks this divergence of opinion is "due entirely to a different understanding of the origin and relations of the cupriferous formation of lake Superior and especially of that portion of it which belongs to the southern shore of the lake" (p. 306.) He proceeds accordingly, to establish the proposition that the cupriferous series of interbedded traps, conglomerates and sandstones are collectively the equivalent of the sandstone extending generally along the south shore. This being so, nothing remains between the cupriferous series and the granite except the indivisible series of rocks which Foster and Whitney had styled the Azoic system.

If we follow Mr. Logan, he says in effect, we must admit that the cupriferous belt lies unconformably beneath the sandstone.

"We must also admit that these cuperiferous rocks are identical in age with the series of quartz beds and jasper conglomerates displayed on the north shore of lake Huron, and hence called 'Huronian.' Therefore, according to Mr. Logan's views, since the cupriferous series of lake Superior rests unconformably on a still lower formation of shales, quartz rock, etc., the rocks of lake Huron must also do the same, although no such fact has been observed. Hence, we must recognize two systems beneath the Potsdam sandstone, one the Huronian, comprising the cupriferous rocks of lake Superior and the formations of the north shore of lake Huron, the other, the Laurentian, including all the rocks of Canada and the Northwest which we should designate by the term 'Azoic,' with the exception of those of lake Huron, as before indicated."

"The principal question to be settled then, is this: What are the relations of the cupriferous rocks of lake Superior? Do they

*J. D. Whitney, "Remarks on the Huronian and Laurentian systems of the Canada Geological Survey," *Amer. Jour. Sci.*, II, 305-394, May, 1857.

constitute a distinct system by themselves, or are they part and parcel of the Potsdam sandstone itself?" And this is the question which Mr. Whitney proceeds to answer affirmatively. Mr. Whitney's two main positions as against those of Sir William Logan, may be stated thus:

1. The cupriferous formation is *not* distinct from the Potsdam.
2. The Huronian rocks are *not* equivalent to the cupriferous.

In *1884*, professor Whitney again returned to a vindication of the integrity of the Azoic system.* In an extended and elaborate memoir, Messrs. Whitney and Wadsworth review all that had been written in America on rocks embraced under the Azoic system. They pursue the method of liberal quotation, in setting forth the views of the various writers, and accompany these by critical remarks. The authors find very little to commend in this literature, but discover many opportunities for caustic comment, seeming almost to forget that possibly the honest search for truth may not lie, precisely in an adoption of the views of the originators of the Azoic system. Still there is a good amount of justice in the following sentence, extracted from their "Resume:"

"We think that it is impossible for any unprejudiced worker in this department of science to peruse with care the preceding pages, and not feel obliged to admit that the geology of a large portion of this country, and especially that of Canada and New England, is in an almost hopeless state of confusion. We thing that it must have been made clear to the candid mind, that the geologist would find himself completely baffled, who should endeavor to obtain any definite knowledge of the real nature and order of succession of the rocks which cover so large a portion of the region in question, from the study of that which has been published with regard to them. We believe that we are justified in going still farther, and saying, that our chances of our having, at some future time, a clear understanding of the geological structure of northeastern North America would be decidedly improved, if all that has been written about it were at once struck out of existence" (pp. 519-520.)

All this tends to prove, as the authors think, that no real progress has been made in azoic geology since 1850. Their impressive resumé embraces the following positions: *First*, No evidence has been presented of the existence of life anterior to the advent of the primordial fauna of Barrande—that is, in those metamorphic rocks which were at first united in a system styled "Azoic." The supposed organism known as *Eozoön*, is only a peculiar arrange-

* *The Azoic System and its Proposed Subdivisions.* By J. D. Whitney and M. E. Wadsworth. *Bull. Mus. Comp. Zoöl.*, Geological Series, vol. i, pp. xvi and 331-365.

ment of crystalline matter. Its organic nature was never consistently defended by Dawson and Carpenter. The segregated, vein-like character of the limestones in which it occurs in eastern Massachusetts, has been affirmed by Burbank, Perry and Dr. Wadsworth, and the final *coup de grace* has been administered by Dr. Möbius. The epitaph has been written by F. Römer and Zittel. As to the organic origin of the crystalline *limestones*, there is nothing whatever to prove it, while the presene of calcite and calcitic formations in metalliferous veins, and in dykes and amygdaloids is sufficient proof that the existence of a limestone does not necessarily imply conditions compatible with organization. *Graphite*, too, instead of being a derivative of vegetable substances is found in the presence of indications of intense heat, and has never been found in such situation as to justify the inference that it resulted from the transformation of coal. As to the origin of masses of *magnetic and specular oxides of iron*, there is nothing in the laws of chemistry to forbid their eruptive nature, while the distribution of iron in meteorites and on the earth, and the evidences touching the mineral nature of the earth's interior, all tend to show the probability that the iron of the earliest times was connected with the agency of heat rather than of organization.

Secondly, As to the admissibility of a subdivision of the azoic rocks, the authors maintain that no adequate ground has yet been presented. They moreover, preclude the possibility of such ground by laying down the canon that observed successions of life are the only justification of a chronological arrangement of rocks. Of course, no successions of life are possible where no life exists. To pronounce a series azoic and demand the application of the palæontological dogma, is to move the previous question without debate. Whether there are or may be, good grounds other than palæontological, for a successional arrangement of terranes, is a question which will be considered in the sequel of this memoir. The mineralogical and lithological bases of various proposed divisions of the Azoic are examined, and besides their exclusion at the threshold by the canon laid down, are represented as inherently conflicting and invalid. Finally, to illustrate the misleading character of mineralogical criteria, they push the principle *in absurdum* by proposing ironically, a division of the Azoic into twelve systems based on predominant mineral characteristics.

This memoir, though characterized by a spirit of dogmatism and wholesale contempt of contemporary research, justified only by the assumption of infallibility in the work of its authors, is still,

a masterly review and a forceful argument, challenging serious reconsideration of the evidences on which many of our recent judgments have been based.

T. Sterry Hunt.

Dr. Hunt's writings on pre-Silurian rocks have been voluminous and long continued. His utterances are largely of an inferential and deductive character, based on the field-observations and judgments of others, backed, however, by numerous personal reconnoissances. He appears to have been to some extent, the expositor and commentator and public representative of the Canadian survey. The value of his work in the aggregate — especially his chemical and mineralogical work, is great. He has made a durable impression on the science of his day. But his proper geological utterances, while always learned and sagacious, have sometimes possessed doubtful value. From lack of close adherence to observations made by himself, and from too much readiness to give utterance to the intuitions of the moment, he has fallen into occasional self-inconsistencies, and many conflicts with his fellow workers in geology. Partly for such reasons, I shall not follow out in detail the varying utterances which during a long life, he has placed on record.

1855. Dr. Hunt appears to have been the first to employ the term "Huronian" in its application to a series of rocks. In "A Sketch of the Geology of Canada," speaking of the rocks on the north shore of lake Huron, then recently studied by Mr. Murray, he says:

"As these rocks underlie those of the Silurian system, and have not as yet, afforded any fossils, they may probably be referred to the Cambrian system (Lower Cambrian of Sedgwick). . . . This *Huronian formation* is known for a distance of about 150 leagues upon lakes Huron and Superior."*

1858. Dr. Hunt suggested evidences of the contemporary existence of organic life in the limestones, graphite and iron ores of the Laurentian.†

On the discovery of *Eozoön* so called, he discussed the mineral-

* *Canada at the Universal Exposition* of 1855, pp. 427, 428. [*Esquisse géologique*, pp. 28, 33. 1855]. Mr. Murray, as we have seen, had already employed the term *Huronian series*. in his report for 1855; but that was not printed till 1857. Neither he nor Hunt employed the term deliberately, as the designation of a well comprehended system of rocks, but only to express the geographical position of certain rocks referred to. In 1857, Sir William Logan made formal announcement to the American Association, that the term *Huronian* had been adopted. See *anté*, pp. 123, 124.

†*Quar. Jour. Geol. Soc.*, xv, 493.

ogical relations of the object, and gave the name *loganite* to a supposed new mineral form.*

In the *Esquisse géologique du Canada,*† Dr. Hunt described the Laurentian system as embracing two distinct series, one resting *discordantly* on the other. These he denominated Lower Laurentian and Upper Laurentian or Labradorian (afterward called by him Norian).

The so-called "Hastings series" was first brought into notice in 1852-3 by Mr. Murray (pp. 103-108), and in the discussion of these rocks, Dr. Hunt frequently participated. In *1863*, he gave analyses of the limestones (*Rep.*, 1863, pp, 592-3). In *1867*, he stated that the Hastings series reposed in *concordant stratification* on the Laurentian gneiss, but that the Upper Laurentian or Labradorian, rested *unconformably*, not only on the Lower Laurentian, but also on the Hastings series.‡

In *1869*, he identified as Laurentian,§ "the great gneissic and hornblendic formation stretching through" the northeastern portion of Massachusetts, and inclosing crystalline limestones, and on the ground of their age, promoted successfully the search for *Eozoön canadense.*

In *1870*, his attention was again turned to the geology of eastern New England,‖ and he recorded the conclusion that, "In fact, the schists and gneisses of the White Mountains are clearly distinct, lithologically, from the Laurentian and the Huronian, as well as from the crystalline rocks of the Green Mountains, and from the fossiliferous Upper Silurian strata, which lie at the southwestern base of the Canadian prolongation of the latter." (p. 84.). Turning then, to the lithological characters of the "Hastings series" in Canada, he says Mr. Vennor has shown that "it rests unconformably upon the old Laurentian gneiss, while it is at the same time overlaid by the horizontal limestones of the Trenton group. This intermediate series which attains a thickness of several thousand feet, is terminated by calcareo-micaceous schists, in which *Eozoön canadense* has been found, both in Madoc and Tudor." (p. 85.) He then summarizes Mr. Murray's observations in Newfoundland in 1866 and recognizes there a mass of rocks "immediately succeeding the Laurentian," and concludes:

"From these investigations of Mr. Murray, we learn that between the Laurentian and the Quebec group, there exists a series

**Geology of Canada*, 1863, p. 490.

†*Paris Exhibition of 1867*, p 10.

‡*Esquisse géologique* pp. 5, 6.

§On Laurentian rocks in eastern Massachusetts, *Am. Jour. Sci.*, II xlix, 75-78.

‖"On the Geology of Eastern New England," *Amer. Jour. Sci.* II, 1, 83-99.

of several thousand feet of strata, including soft, bluish-gray mica slates and micaceous limestones belonging to the Potsdam group; besides a great mass of whitish granitoid mica slates whose relation to the Potsdam is still uncertain. To the whole of these we may perhaps give the provisional name of the *Terranovan series*, in allusion to the name of Newfoundland." (p. 87.)

The Terranovan series therefore occupies a portion of the interval in which lies also the "Norian" and the "Huronian," and it overlaps the Potsdam. To this he referred the White Mountain rocks, as well as certain rocks in New Brunswick.

In *1868*, he prepared a memoir on the mineralogy of the "Laurentian limestones of North America*" in which he wrote:

"In the county of Hastings, in the Province of Ontario, not less than 21,000 feet of strata, consisting of crystalline schists, limestone and diorite are found resting *conformably* upon Laurentian gneiss." (p. 48.)

In a postscript (p. 98,) he states:

"More recent researches by the Geological Survey of Canada have shown that the rocks of Hastings county, Ontario, noticed on page 48, rest *unconformably* upon the Laurentian, and belong to one, and possibly two, distinct systems. The upper and larger portion consists in great part, of mica schist and micaceous limestones, while at the base are great masses of dioritic and hornblendic schists, with iron ore, posssibly of Huronian age."

In *1873*, he was reported as follows:

"As regards the *Norian*, which had been once joined to the Laurentian, he had elsewhere shown that we had reason for suspecting that it might be more recent than the Huronian, and possibly than the *Montalban*, a conclusion which appeared to be confirmed by the facts made known by Hitchcock."†

In *1875*, he returned to a study of the White mountains, or Montalban series, which he had already identified with the Hastings series. He said:

"These ancient rocks are also largely represented in Hastings county, Ontario, where they occupy a position between the Laurentian [i. e. Lower Laurentian] and the fossiliferous limestones of the Trenton group, and are the equivalents of similar limestones and micaceous quartzytes in Berkshire county."‡

In *1878*, Dr. Hunt referred the limestones of the Hastings series

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**Twenty-first Annual Report of the Regents of the University of the State of New York*, Appndix, pp. 47-98.

†*Proc. Bost. Soc. Nat. Hist.*, 1873, xv, 310.

‡*Proc. Soc. Bost. Nat. Hist.*, 1875, xvii, 509.

to the lower Taconic (Taconian).* In his "Chemical and Geological Essays," the Hastings limestones and slates are said to lie between the Huronian and Trenton.

In *1878*, he prepared a synopsis † of his views on the classification of Eozoic (Archæan, Azoic) rocks. Their divisions were distributed as follows:

1*d*. MONTALBAN. Named in 1872[=Terranovan], well displayed in the White Mountains, and occupying large areas in New England and southwestward; a great mass of crystalline schists. Gneisses distinguished from those of the Laurentian by being finer grained and having white feldspar. They are less firm and more tender, often containing silvery mica, and pass into coarser mica schists. This series contains granular olivine rocks [*dunite*] often accompanied by enstatite [*saxonite* of Wadsworth].

1*c*. HURONIAN. Named in 1855, more or less schistose, crystalline rocks, resting unconformably on the Laurentian. "The Green mountain series." Contain jaspery petrosilex, becoming porphyritic by the presence of feldspar and of quartz in a compact base, sometimes schistose and finely laminated. Contain basally, chloritic schists altered from diabases. [The description applies to the lake Superior pseudo-Huronian, not to the original lake Huron Huronian.]

1*b*. NORIAN. The upper portion of the Laurentian series on the Ottawa river. A distinct terrane, resting unconformably upon the gneisses and crystalline limestones of the Laurentian. The former Upper Laurentian or Labradorian. Consists chiefly of anorthic [triclinic] feldspar, sometimes almost without admixture; sometimes accompanied by small portions of hornblende, of pyroxene or of hypersthene (hypersthenite or hyperite). Fine or coarse. Colors white, pale bluish or greenish, dark lavender, smoke-blue or nearly black. Titaniferous iron occurs in great beds.

1*a*. LAURENTIAN. Named in 1854, prevailingly a strong, massive gneiss, reddish or grayish, sparingly micaceous, very often hornblendic. The crystalline schists absent. Crystalline limestones present, often associated with beds of quartz. Masses of magnetite. Beneath these (the *Grenville series*) a great mass of granitoid gneiss without limestone (the *Ottawa gneiss*).

Above the Montalban is placed the TACONIAN (=Lower Taconic); QUEBEC group (=Upper Taconic or Cambrian), (pp. 10, 11, 12, 13, 21).

**Proc. Bost. Soc. Nat. Hist.*, 1878, xix, 278; preface to second edition of *Chem. and Geol. Essays*, pp. xxii, xxvi.

†*The Geologists' Traveling Handbook.* By Dr. James Macfarlane, New York, 1879. It was circulated before the close of 1878.

The following is Dr Hunt's view of the taxonomy of the lower rocks in his Pennsylvania Report:*

8. SILURO-CAMBRIAN. Upper Cambrian of Sedgwick. Part of Lower Silurian of Murchison, and the Matinal of Rogers, in part.

7. CAMBRIAN. The Lower and Middle Cambrian of Sedgwick, and the Lower and Upper Cambrian of Hicks; being the Upper Taconic of Emmons, and the Quebec group of Logan: or the Primordial Silurian, and part of the Lower Silurian of Murchison. [Upper Copper-bearing rocks of Logan.]

6. KEWEENIAN. The Copper-bearing series of Lake Superior, found in the same geological interval as the Taconian, but not identified with it.

5. TACONIAN. The Lower Taconic of Emmons, or the "Hastings series," including a part of the Primal, Auroral and Matinal divisions of Rogers; and constituting with the Montalban, what he had once called Terranovan.

4. MONTALBAN. The White Mountain or Mica schist series. [Terranovan in part.]

3. HURONIAN. The Green Mountain series, or altered Quebec group of Logan. [Lower Copper-bearing rocks of Logan.]

2. NORIAN. The Labradorian or Upper Laurentian of Logan.

1. LAURENTIAN.

   b. *Grenville series.* With limestones. Supposed unconformable with the next.

   a. *Ottawa gneiss.* Without limestones. (pp. 215-242.)

In *1879*, the Norian was said by Dr. Hunt to rest *unconformably* upon the gneisses and crystalline limestones of the Laurentian, and held to be older than the Huronian. The Huronian was also said to rest *unconformably* on the Laurentian on the north shores of lakes Huron and Superior.

In *1886*,† Dr. Hunt's conception of the succession of the Azoic Rocks was freshly set forth with a result of which a brief abstract is as follows:

SILURIAN.

ORDOVICIAN.

CAMBRIAN.

KEWEENIAN. Upper division of Upper Copper-bearing series.

**Special Report on the Trap Dykes and Azoic Rocks of southeastern Pennsylvania.* By T. Sterry Hunt. Part I. Historical Introduction. Harrisburg, 1878 pp. 253. [Being E of the series of Survey Reports. This Report is dated 1875, though the Preface bears date 1878.]

†*Mineral Physiology and Physiography*, a second series of Chemical and Geological Essays, with a General Introduction. Boston, 1886, 8vo, pp. xvii plus 710.

TACONIAN. Lower division of Upper Copper-bearing series. Quebec group of Logan.

MONTALBAN.

HURONIAN. ?*Pebidian* of Hicks.

ARVONIAN. (Formerly part of Huronian.) Petrosilex series,—jaspers and porphyry. *Hälleflinta*, Sweden. *Arvonian* of Hicks.

NORIAN. (Formerly Upper Laurentian or Labradorian.)

LAURENTIAN. (Former Lower Laurentian.) ?*Lewisian* of Murch.

Grenville series. Typical Laurentian (Former Middle Laurentian.) *Dimetian* of Hicks.

*Ottawa gneiss.**

Dr. Hunt has always been resolutely opposed to the identification of the Animike Series with the proper Huronian. The following passage, among many others is explicit:

"The fact that the Taconian or Animike series in Northern Michigan, rests sometimes upon the Granitoid or Gneissic group, sometimes upon the Dioritic group, of Rominger, and elsewhere upon a mica schist series having the characters of the Montalban, goes far to show its stratigraphical distinctness from all three of these. Its separation from the Dioritic group was early noticed by Logan, when he described the unconformable superposition of this series (the lower division of his Upper Copper-bearing series) on the ancient greenstone (Huronian) series, and the presence of portions of this in the basal conglomerates of the latter. There are, however, as I have elsewhere noticed (*Azoic Rocks*, p. 202,) certain mineralogical resemblances between the Taconian and the softer and more schistose beds of the Huronian, with which they were confounded by Murray at more than one locality along the north shore of Lake Superior. Hence, after visiting the Marquette district in 1861. he did not hesitate to call the iron-bearing series of that region Huronian; a designation adopted by the Geological Survey of Canada. In this he was followed by J. P. Kimball in his study of the Marquette iron ores in 1865, by Hermann Credner in 1869, by T. B Brooks in 1873 and again by Irving in 1883. All of these include the two series under the common name of Huronian, and the estimates of the thickness of the Huronian have

*The following references may be made to opinions of Dr. Hunt on the geology of New Brunswick: Hunt: *Geology of Canada*, 1866, pp. 235, 236; *Amer. Jour. Sci.*, II, 1870, l, p 89 (Compare *Proc. Amer. Assoc.*, 1871, p. 33;) *Azoic rocks*, 1878, 181, 188, 189; *Proc. Amer Assoc.*, 1873, B, 116, 117; 1879, 285-7; *Amer. Jour. Sci.*, 1880, III., xix, 273-5; *Boston Proc.*, 1875 xvii, 509; *id.*, xix, 278; Preface, 2d. ed. *Chemical and Geological Essays*, p. xxix; *Mineral. Physiology and Physiography*, pp. 407-8, 572-4.

been based upon that of the two united. The distinctness of the underlying Dioritic group with its serpentines and chloritic rocks, which together constitute the Huronian or *pietre verdi*—alike from the older granitoid and gneissic group, from the mica-schist or Montalban group and from the great overlying Animike or Taconian system, including the quartzites, marbles, iron-ores and argillites, is however, manifest. The succession is thus brought into complete accordance with that which is found in many parts of the Appalachians, as well as in southern Europe, as is pointed out in part iv of Essay X."*

Dr. Hunt, in other passages, recognizes the presence of the Animike (Taconian) or true Huronian in the Upper Peninsula of Michigan. He writes:

"Resting in some cases upon this group† and in others upon the granitoid rocks is a great system divided in ascending order by Rominger, in 1880, into a Quartzite group (which includes a marble series,) an Iron-ore group, and an Arenaceous-slate group, all of which appear closely connected. The system comprises heavy beds of quartzite, often schistose and with conglomerates, interstratified and overlaid by argillites of various colors, with graphitic, hydro-micaceous or sericitic slates, beds of jasper, of hæmatite and magnetite, either pure or disseminated, and, in the upper portion, limonite and siderite. The limestones form in the upper part of the quartzite division, great masses of white crystalline marble, sometimes with mica and tremolite and sahlite; at other times they are reddish or dull and compact. The iron ores appear to be in two horizons, one below and one above a great body of limestone. To the latter are referred the ores of the Gogebic and Menominee districts, and to the former, those of Marquette and Felch mountain, with which those of Vermilion lake in Minnesota, appear to be identical. The argillites which overlie the latter are those seen in the St. Louis river and at Thompson, Minnesota, which are by Rominger compared with argillites at L'Anse and Huron bay."‡

George F. Matthew and Associates in New Brunswick.

Several different Canadian geologists have participated in the investigation of the geology of the maritime provinces of British North America. The pioneer among them was the present Sir William Dawson, whose special studies for the greater part, have

Mineral Physiology, 581-2.
†The Dioritic group of Rominger.
‡*Mineral Physiology*, pp. 579-80. The writer has elsewhere recorded his independent recognition of the existence of two discordant systems in the Marquette Iron region—*Sixteenth Annu. Rep. Minn.*, pp. 178-9, 185.

Brunswick.

7-78.	Bailey, 1880.	Bailey, Matthew & Ells, 1878-9.
	Certain feldspar porphyries.	Silurian. Cambro-Silurian. Cambrian or Primordial.
dial	Upper Kingston gr.	
and stal old-	Lower Kingston. Coastal gr. Talc schists. congl. limestone. Coldbrook gr. Felistic.*14* etc.	Kingston Division: *16*. Felsite, schist, slate cong., felsite cong. and clay slate. Coastal Division: Chloritic, felspathic and talcose; schistose cong. Coldbrook Division: Petrosilex and felsite, agglomerates, diorites, etc.
olo- and	Finer gneiss, quartzites =?Hastings. Coarse gneiss.*15*	Syenite and gneiss, quartzite, felsite, limestone, mica and felsite schists. Syenite-gneiss and felsite.

ut, from its lithological characters placed in the Huronian.]
Coastal overlies them.
ilurian in Rep. of 1874-5. pp. 84-9.
).

vidence of at least a partial unconformability."
blocks, or what appear to have been detached masses of gneiss
ed in, the granite in such a way as to look like a coarse con-

· of Lake Superior.

been palæontological.* Among those who have contributed important original observations and have studied especially the oldest rocks, are George F. Matthew, L. W. Bailey and R. W. Ells. This portion of the continent presents great geological difficulties, and the interpretations of the phenomena have been very diverse. The differences, however, have been rather of local than of geognostic significance; and it is therefore not intended to trace the historical development of opinion into detail. Following Sir William Dawson, Mr. George F. Matthew, in 1863, presented the results of a well elaborated series of observations on the geology of St. John county, New Brunswick† and proposed an arrangement of the rocks which will be reproduced synoptically in the following table.‡

The table which follows is compiled from papers cited in this connection.

CHARLES H. HITCHCOCK.

Professor C. H. Hitchcock's survey in the state of Maine did not lead him into researches possessing any important bearing on the development of American opinion respecting the nature and origin of the older rocks. The official character of his connection with the Vermont survey, the first volume of the final report of which was published in 1861, though prepared in 1859, was as chemist of the survey. But, provision for the chemical work being inadequate, professor Hitchcock devoted much attention to geological investigations. Among these was the preparation of a chapter on "Azoic Rocks" and contributions on "Steatite and Serpentine" and "Saccharoid Azoic Limestone."§

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*Acadian Geology. *The Geological Structure, Organic Remains and Mineral Resources of Nova Scotia, New Brunswick and Prince Edward's Island.* First edition, 1855, 2d, 1868 (with information posted to date), 3d, 1878. For other recorded opinions of Sir William Dawson, see *Can. Nat. and Geol.*, 1861, I, vi, 164; *Quar. Jour. Geol. Soc.*, 1862, xviii, 303. Sir W. E. Logan made a reconnoissance of the Bonaventure formation in 1843; and Dr. Abraham Gesner made a report to the New Brunswick government at nearly the same date.

†*Canadian Naturalist and Geologist*, viii, 241-260, Aug. 1863. For later views see *Quar. Jour. Geol. Soc.*, 1865, xxi, 422-434.

‡The later studies of Messrs. Matthew, Bailey, Hartt, Ells and others may be consulted as follows: Bailey: *Canadian Naturalist*, 1864, 81-97 (a rapid reconnoissance); Bailey, Matthew and Hartt: *Observations on the Geology of Southern New Brunswick*, 1865: H. Y. Hind: *Prelim. Report on the Geol. of New Brunswick*, 1865; Bailey and Matthew: *Proc. Amer. Assoc.*, 1864, xviii, 179-195 (revised to April, 1870); Bailey and Matthew: *Geol. of Can. Report of Progress*, 1870-71, 13-240 (proposing numerous changes on recommendation of Dr. Hunt); Matthew: *Report*, 1874-5, pp. 84-9; *Report* for 1876-7, 322-350; Hugh Fletcher: *Same Report*, 405-426; R. W. Ells: *Rep. Prog.* for 1877-8, D., pp. 1-12; L. W. Bailey: *Rep.* 1877-8, DD., pp. 1-34; G. F. Matthew: *Same Rep.*, E, pp. 1-6; Bailey, Matthew and Ells: *Rep.*, 1878-9, D., pp. 1-26; R. W. Ells: *Rep.*, 1879-80, D., pp. 30-42; *Rep.*, 1880-82, D., pp. 17-19: Bailey: *Proc. Amer. Assoc.*, 1880, 416, 417: *Can. Rep.*, 1882-4, E., pp. 31-34; A. P. Low: *Rep.*, 1882-4, F., pp. 16-20; R. W. Ells: *Rep.*, 1885, E. pp. 54-63. Dr. T. S. Hunt's recorded opinions have been already referred to, *Ante.* p. 150

§*Geology of Vermont*, I, pp. 452-474 and 533-558.

In consonance with views generally prevailing at the time, he expresses the opinion respecting the azoic rocks, that "stratification and lamination appear to have been produced by original deposition in water." Speaking of the difficulty of distinguishing, in some cases, between the lines of sedimentary structure and cleavage and foliation, he says: "We have not attempted it [distinction of cleavage] to much extent in the slates of Vermont; still less have we tried to draw a line of distinction between the foliation of the schists and stratification; for this is a still more difficult work. Hence the strikes and dips which we shall give are those of foliation and cleavage. But we believe that these usually correspond essentially with the stratification. In the fossiliferous clay-slates of the western part of the State, as well as in the limestones, we not unfrequently have found the cleavage planes making quite an angle with those of the original deposition; but in all those belts of slate interstratified with the more thoroughly metamorphosed schists, the two seem usually coincident." (p. 452.)

No attempt is made to give the azoic rocks either a systemic, a geognostic or a chronological arrangement. Fifteen species are enumerated and lithologically described. Five and a half quarto pages are devoted to a catalogue of isolated instances of strike and dip, though very little attempt is made to correlate them in a general system of structure. It is stated however, that three distinguishable ranges of gneiss traverse the state: the Green mountain range, the middle range and the Connecticut river range. The first of these is thought a continuation of the Hoosac mountain range—the gneiss of the Green mountains resulting from the accession of feldspar to the mica schist of Massachusetts, though often, in Vermont, passing again into mica schist. Of some of the gneiss of the range along the Winooski, he says "it resembles sandstone—the crystals of feldspar being rounded like large grains of sand. (p. 465.) The middle range is less extensive and more distinctly gneissic. Eastward it graduates into mica schist. The gneissic range near the Connecticut river consists only of three patches."

The unessential character of the recognized distinction between gneiss and mica schist, as indicated in the transitions along the strike, mentioned above, is emphasized by further statements. "Those layers of the rocks" he says, "on both sides of the mountain, which all would regard as gneiss, are generally interstratified with other layers of mica or talcose schist and quartz; and the judgment of good observers would differ about the line where the gneiss predominates over the schists." "Also, as we pass norther-

ly along the line of strike [of the Green mountain range] along the eastern margin, the gneiss is rapidly succeeded by mica and talcose schists..** We incline to the opinion, however, that a narrow belt of Green mountain gneiss does extend across the whole State of Vermont.** We have expressed the opinion in another place, that gneiss, mica and talcose schist, and even some beds of quartz, may be only metamorphic varieties of the same original formation." (p. 470.)

Of hornblende rock he says: "It is found associated with gneiss and clay-slate in positions much like dikes, as well as in regular beds." Referring to the opinion expressed by MacCulloch, that hornblende rock and hornblende schist may result from the metamorphism of clay-slate, professor Hitchcock states that Bischof has shown it possible that "even in lava, the hornblende [sometimes present] was not formed at the time of the protrusion of the lava, but subsequently in the wet way; and the associations of hornblende schist forbid the idea that it was a volcanic product."

In reference to steatite and serpentine, professor Hitchcock states that "there are at least sixty beds of steatite in Vermont, and twenty-five beds of serpentine. The aggregate of serpentine is more than double that of steatite. Regarding the steatite and serpentine rocks as of one age in each range, he concludes that there are four ranges, and that these are of different ages.

As to origin, he regards serpentine as originally stratified, referring to its conformability with the foliation of the rocks which embrace it. There is no protruded serpentine in Vermont. Steatite, probably, had a similar origin. He believes in the change of "some beds of hornblende schist and diorite or greenstone, into serpentine." (p. 554.)

In general connection with the subject of metamorphism, professor Hitchcock makes the following just remarks:

"The distinction between stratified and unstratified rocks has been usually regarded as one of the most trenchant and reliable in the science of geology. And so long as it was considered a certain fact that the stratified rocks were exclusively deposited by water, and the unstratified all resulted by dry heat, it is not strange that geologists should have looked upon the line between the two classes as very distinct and recognizable. But now that it is so generally admitted that hot water has been the most efficient agent in metamorphosing the stratified rocks, and converting some of them into the unstratified, we can see how the distinction between them should often be very obscure and uncertain. Such is certainly the case with serpentine and dolomite, both of which are

sometimes stratified and sometimes unstratified. We are apprehensive that some other system of classification must be adopted, to include such rock and also such varieties of gneiss, and even some of the schists." (pp. 554-5.)

The results of the studies of professor Hitchcock and his collaborators in the geology of New Hampshire are embraced in three massive royal octavo volumes.* They embody a vast amount of faithfully elaborated information in a region of extreme difficulty, which had hitherto received vastly less geological than mineralogical study. The state presented extraordinary difficulties, arising, *first*, from the absence of organic remains, those time-marks by which the geologist is able to recognize his position in the progress of æons past, and *secondly*, from the destruction of the traces of superposition by those orogenic disturbances which almost wholly obliterated the records originally made; and *finally*, by the metamorphism which had not only transformed the aspects and constitution of rock-masses, but had effected alterations of such varying nature and degree as to defy identification by the usual resemblances. In this trackless geological wilderness the geologist entered, meagrely equipped for his great work, and reported to the state and to the world the progress made from year to year, until lapse of time and exhaustion of means rendered it imperative to pronounce final verdicts. As a matter of obvious necessity, the geological conception underwent revision and augmentation with every season's addition of knowledge. But it was a peculiar merit of professor Hitchcock's advancing work that he was ever ready to announce the shape which his conception of the State's geological structure and history had attained after the latest acquisitions of observed fact. A less unsuspicious mind—perhaps it might be said, a more judicious method, would have enforced more reserve. The difference would be that a more prudent investigator would have reached thoughts not more mature and final, but would have held his "best thoughts" in reserve; while Hitchcock freely shared them with the public. It has been found possible to cast censure on professor Hitchcock that his annual announcements of status reached were so conflicting and changeful; but a just and generous view must regard them simply as marks of the progress of ideas, and encouragments to all who may be grappling with equal difficulties.

***Geology of New Hampshire.* By C. H. Hitchcock, J. H. Huntington, Warren Upham and G. W. Hawes, Volume i, containing Part I, (1874) "Physical Geography," 668pp; Volume ii, (1877,) containing Part II, "Stratigraphical Geology." 685pp; Volume iii, (1878), containing Part III, "Surface Geology," Part IV, "Mineralogy and Lithology," Part V. "Economic Geology."

It occurs to the writer that it may be best to present first, the series of provisional conclusions announced by professor Hitchcock in the progress of his work. These are taken substantially as compiled by Whitney and Wadsworth—the order of arrangement being inverted, in conformity with the method of this memoir.*

ANNUAL REPORTS. 1869-1872.

First Annual Report, 1869.

Upper Schists.
Quebec Group.
  Auriferous Conglomerate.
  Clay Slate.
  Copper Belt.
  Lower (mostly green) Schists.
  Staurolite Schists.
White Mountain series (Gneissic, Granitic)

2d Annual Report, 1870.

Clay Slates.
Calciferous Mica Schist.
Coös Group.
Lower Silurian.
  Quebec Group.
  Merrimac Group.
Common Granite.
Porphyritic Granite.
Laurentian (?) Exeter Syenites.
Eozoic (White Mountain or Gneissic Series).
  Soapstones.
  Limestones.
  Quartzyte.
  Porphyritic Granite.
  Syenite.
  Granite.
  Chiastolite Slates.
  Andalusite Gneiss.
  Feldspathic Mica Schist.
  Granitic Gneiss.
  Ferruginous Gneiss.
  Normal Gneiss.

3d Annual Report 1871.

Coös Group.
Clay Slate and Quartzytes.
Laurentian (?).
  Norian.
  Brecciated Granite.
  Trachytic Granite.
  Common Granite.
  Andalusite Gneiss (White Mountain Gneiss),
  Gneiss.
  Bethlehem Gneiss.
  Porphyritic Gneiss.

4th Annual Report, 1872.

Division 3.

Andalusite Slates of the Coös Group.
Mica Schist.
Quartzyte.
White Mountain Series.
  Andalusite Gneiss, Ordinary and Imperfect Gneiss, the Concord and Fitzwilliam Granite, Soapstone and Limestone.
Granite Gneiss.
Laurentian.
  Granite and Porphyritic Gneiss.

Division 2.

Norian (Pemigewasset Basin).
  Green Granite and Syenite.
  Four Series of Compact Feldspar.
  Spotted Granite.
  Common Granite.
Laurentian.
  Franconia Breccia.
  White Mountain or Andalusite Gneiss.
  Bethlehem and Berlin Gneiss.
  Porphyritic Gneiss and Granite.

Division 1.

Helderberg.
Cambrian.
  Coös Group.
    Decomposing Slates, Dikes.
    Calciferous Mica Schist.
    Mica and Argillaceous Schists.
    Quartzytes, Staurolite Schists.
  Auriferous Clay Slates.
Huronian.
  Conglomerates and Quartzytes.
  Hydromica and Talcose Schist.

PROC. AMER. ASSOC. ADV. OF SCI., 1872. xxi, 134, 135, 150.

II. Palæozoic.
    Clay Slates.
    Helderberg Limestones,
I. Eozoic.
    5. Older Cambrian.
        Merrimac Group and probably Calciferous Mica Schist of the Vermont survey.
        Coös Group.
    4. Huronian.
        The Talcose Schist Series.
    3. Exeter Syenites.
    2. Norian.
        f. Red compact and Crystalline Orthoclase Felsite.
        e. Dark compact Orthoclase Felsite.

Bull. Mus. Comp. Zool., Vol. vii., p. 396.

d. Compact Labradorite Felsite.
c. Ossipyte.
b. Trachytic Granite.
a. Common Granite.

1. Laurentian.
f. Range of Gneiss between Whitefield and Milan, considerably Hornblendic.
e. Gneiss on both flanks of the Porphyritic variety in the south part of the State, carrying the Concord and Fitzwilliam Granite, and is probably the Beryl-bearing Series.
d. Gneiss of Lake Winnipiseogee Basin.
c. Bethlehem or Talcose Gneiss.
b. White Mountain Series or Andalusite Gneiss.
a. Porphyritic Gneiss.

PROC. BOSTON SOC. NAT. HIST., 1873. xv, 304-309.

V. Palæozoic.
B. Clay Slates.
A. Helderberg Limestone.

IV. Mostly Cambrian (?).
F. Mount Mote Conglomerates.
E. Green Granite.
D. Clay Slates.
C. Coös Group.
B. Merrimac Group.
A. Mica Schists of Rockingham County.

III. Huronian.
Feldspar and Talc.
Whitish Schists.
Green Schists.
Talcose and Auriferous Conglomerates.

II. Laurentian.
H. Syenites of Exeter and Tripyramid.
G. Reddish compact Orthoclase.
F. Red compact Orthoclase.
E. Dark compact Orthoclase.
D. Dark compact Labradorite.
C. Ossipyte.
B. Spotted Granite.
A. Common Granite of the White Mountains.

I. Laurentian (?).
C. White Mountain or Andalusite Gneiss.
B. Bethlehem Gneiss.
A. Porphyritic Gneiss.

PROC. AMER. ASSOC. ADV. SCI., 1873. xxii, 120-131.

Winnipiseogee Lake.

Eozoic.
Mica Schist.
Eruptive Syenite.
Labradorian.
Felsites or Compact Feldspars.
Eruptive Granites of the Ossipee Mountains.
Laurentian (?).
White Mountain Series.
Winnipiseogee Lake Gneiss Formation.
Porphyritic Gneiss or Granite.

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Helderberg Period.
Mica Schist Period.
Coös Group.
Cambrian Auriferous Clay Slates.
Merrimac Group.
Rockingham Mica Schist.
Eozoic.
Huronian.
Conglomerate.
Serpentine with Silicious Schist and Dolomite and Soapstone.
Copper and Iron Beds.
Labrador.
Eruptive Syenite.
Fine Sedimentary Deposits.
Chocorua Granite.
Albany Granite.
Conway Granite.
Atlantic.
Franconia Breccia Group.
Montalban.
Lake Gneiss.
Bethlehem.
Laurentian.
Porphyritic Gneiss.

WALLING'S ATLAS OF NEW HAMPSHIRE, 1877.

Palæozoic,
Silurian.
Slates, Conglomerates, etc.
Helderberg Limestones.
Cambrian.
Mt. Mote Conglomerate.
Clay Slates.
Coös Group.
Calciferous Mica Schists.
Rockingham Schists.
Huronian.
Auriferous Conglomerate.
Lyman Group.
Lisbon Group.
Labrador or Pemigewasset.
Exeter Syenites.
Compact Feldspar.
Ossipyte.
Chocorua Granite.
Albany Granite.
Conway Granite.
Atlantic.
Franconia Breccia.
Montalban or White Mountain Series.
Lake Winnipiseogee Gneiss.

Bethlehem Gneiss.
Laurentian.
Porphyritic Gneiss.

GEOLOGY OF NEW HAMPSHIRE, 1877.
ii, 674, 675.

I. Stratified Groups.

Palæozoic.
Lower Helderberg.
Calciferous Mica Schist.
Coös Group.
Staurolite Slate.
Mica Schist.
Quartzyte.
Cambrian Slates.
Palæozoic (?).
Kearsarge Andalusite Group.
Rockingham Mica Schist.
Merrimac Group.
Ferruginous Slates.
Eozoic.
Upper Huronian.
Auriferous Conglomerate.
Lyman Group.
Lisbon Group.
Swift Water Series.
Hornblende Schist.
Lower Huronian.
Labrador.
Montalban.
Franconia Breccia.
Fibrolite Schists.
Ferruginous Schists.
Concord Granite.
Gneiss and Feldspathic Mica Schists.
Laurentian.
Lake Winnipiseogee Gneiss.
Bethlehem Fine-grained Gneiss.
Bethlehem Ordinary Gneiss.
Porphyritic Gneiss.

II. Eruptive Masses.

Augitic.
Diabase.
Diorite.
Feldspathic.
Trachyte.
Pequawket Breccia.
Porphyry.
Labradorite Diorite.
Granitic.
Exeter Syenite and Diorite.
Syenite of Mt. Gunstock, &c.
Granite not otherwise Assigned.
Granite cutting Coös Group.
Chocorua Series.
Albany Granite.
Conway Granite.

In a region where palæontological aids to investigation are wanting, the geologist must rely on indications of superposition, physical conformities, characteristic minerals and petrographic resemblances. The application of the petrographic criterion is involved in distracting difficulties by the progressive and unequally-paced changes which crystalline aggregations have undergone in the presence of the dynamic agents of geology. Hence the greater necessity for seeking always the evidences from superposition. Professor Hitchcock, with a true evaluation of the only expedients available, enunciated in 1873, the fundamental principles by which he was guided:

"Logan, in 1855," he says, "described a system of rocks overlying unconformably the Laurentian gneisses about Lake Huron, which were distinguished by means of lithological characters. All geologists, therefore, who use the name Huronian, of necessity practically adopt this principle, though perhaps insensibly. We do not claim that a talcose rock can never be found in any other system than the Huronian, nor that gneiss may never be stratified with the hydromicas. Professor Dana's recent paper shows that gneisses, quartzites and limestones are interstratified in the Silurian of western New England.* In no instance would we claim that mineral character is sufficient to distinguish systems without

Proc. Amer. Assoc., 1873, Sec. B, p. 147.

a study of the relations of the strata. We may sometimes generalize, and believe that rocks of similar mineral characters must be of the same age, but such speculations must always provide for confirmation by a study of the strata."*

An application of the mineralogical criterion is seen in what, in the report for 1870, is called "porphyritic gneiss."

"There are over Thirty areas of porphyritic gneiss in which the feldspar crystals are very conspicuous for their size, the rock being the *Augen-gneiss* of Europe. I assume that all the areas of this rock are identical in age, and in speculating upon the relative positions of the intervening groups, rely upon the correctness of this starting-point.** The fact of minor differences would seem to confirm our assumption of their identity in age, just as the palæontologist finds, from the presence of the same fossils, proof of contemporaneity in the rocks with dissimilar mineral character. From these facts it is inferred that the porphyritic gneiss is older than the Lake or the Montalban gneisses, the last being the newest.** It may as well be said now as at any time, that nothing older than the porphyritic gneiss has yet been discovered. This formation constituted the first dry land in the State."†

Professor Hitchcock's changes of opinion are illustrated in his record in reference to the Norian. This division, following Hunt, was first introduced into the report for 1871. Of its relative position he says:

"All will agree that the mineral labradorite belongs to the original Laurentian system; and therefore, by its discovery in New Hampshire, will be satisfied that some of our crystalline rocks belong to the older series of the Eozoic, and not the Palæozoic. Hence the prevalent opinion respecting the age of the New England metamorphic rocks must be changed to conform with the discovery of labradorite in our state.* * Our conclusions as to the absolute and relative ages of the New Hampshire formations depend upon the reference of some of them to the Norian system of Hunt."‡

Professor Hitchcock, therefore, in establishing the high geolog-

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Pro. Amer. Assoc., 1873, Sec. B. p. 147.

†*Final Report* vol. ii, pp. 659, 660, 663, 664.

‡*Report, 1871*, pp. 4-10. The allusion made in the above paragraph may be illustrated by the following citations: "To the Chemung and Portage group of New York* * may perhaps be referred, in part, the rocks of the White Mountains (Hunt, *Amer. Jour. Sci*. 1850, II. ix, p. 19; *Proc. Amer. Assoc.* 1849, II, pp. 333,334.) "It is moreover probable that the rocks of New Hampshire, including the White Mountains, are altered strata of Devonian age." (Hunt, *Geol. of Canada*, 1863, p. 598.) The same opinion was reiterated in 1867 (*Esquisse géologique du Canada*, p. 23; *Bull. Soc. géologique de France*, 1867, II, xxiv. p. 687.) In 1860, professor J. P. Lesley expressed the opinion that the range of the White Mountains would prove to be synclinal instead of anticlinal, and therefore of probable Devonian age. (*Proc. Acad. Nat. Sci. Phil.*, 1860. xii, pp. 363-364.) Logan, also, accord-

ical antiquity of the White mountains, had a long-strengthening sentiment to combat. It was recognized however as Norian by Hunt, in 1873.*

In 1872, Hitchcock more formally defended the supposed sedimentary character of these rocks:

"It is a perplexing matter to determine the lines of stratification, as the outcrops are divided by two prominent sets of jointed planes, either of which might be called layers of deposition, the rock being essentially homogeneous. One set dip 20° northerly, and are the most numerous, The other dip about 75° W 10° S."†

In the Report for 1872, published later than this, he adds:

"As the latter [joints] correspond better in position with the supposed strata of nodular gneiss, it was thought they indicated the proper lines of deposition."‡

These beliefs were iterated in 1872. Referring to the same locality and the same terrane, he says:

"The rock seems to be stratified, its planes dipping about 20° northerly * * The importance of this discovery may be best appreciated by remembering that the presence of the lime feldspars affords a strong presumption that the rocks are Eozoic, and not metamorphic Palæozoic formations. It seems to be generally admitted by geologists that the feldspars are confined to the older rocks, except as found in eruptive trappean and volcanic masses."§

In the second volume of the Final Report, he adheres to the same opinions:

"I was at first satisfied that this rock was gneiss, but did not recognize its true place in the porphyritic group. Subsequently I referred it to the "trachytic" or Albany granite, but a re-examination in 1875, shows that it belongs to the oldest of our formations, and is distinctly stratified, traversed by trap dykes, and narrow banded veins of quartz * * The labradorite rocks with a very moderate dip, rest unconformably upon the greatly upturned edges of the Montalban schists, as if there had been large upheavals at the close of the Montalban period, and comparatively little disturbance since. * * The facts as interpreted, are of great consequence, since they fix the geological horizon of the whole

ing to Hunt, regarded them as probably "altered Devonian strata" (*Azoic Rocks* pp. 86. 87, 182.) (See also *Amer. Jour. Sci.*, II, ix, 19, 1849; II, xxxi. 403, 1831.) In 1870, Hunt pronounced the White mountains Terranovan. *Amer. Jour. Sci.*, II. l. 83-90, 1870. The various older opinions are reviewed at length by Hitchcock in Final Report, ii, 184, 196, 264-7.

**Proc. Boston Soc. Nat. Hist.* xv, p. 310, 1873.

†"The Norian Rocks of New Hampshire," *Amer. Jour. Sci.* III, iii, 43-47, 1872.

‡*Ann. Rep. 1872.*, pp. 15, 16.

§*Proc. Amer. Assoc.*, *1872.*, xxi, pp. 135-151.

Atlantic system, while considerations of a stratigraphical character confirm this impression. * * The discovery of the Labrador system, overlying the most abundant and characteristic White Mountain strata, makes it clear that the latter are older than the former, which are confessedly Eozoic."*

In spite of this oft repeated conviction of the sedimentary nature of these labradorite rocks, and of their occurrence in seven different areas among the White mountains, we find professor Hitchcock on a later page of the same volume, employing the following language:

"The Labrador system, if present in New Hampshire, is in very limited amount. Recent investigations make it difficult to say that the labradorite rocks are not of eruptive character. They have the composition of dolerite; and certain exposures of them upon Mount Washington are surely injected dykes. Hence great doubt arises whether the larger area of Waterville really represents the Labrador system of Canada. At all events, its age is great, for these dykes cut through the Montalban strata [He had very recently said the labradorite rocks rest discordantly on the upturned edges of the Montalban]. This dolerite may be regarded as one of the oldest eruptive rocks in the State, coming to the surface in what was the labrador age of the world."†

The eruptive nature of this mass was detected by Dr. Hawes; and is recorded in the third volume of the New Hampshire report, dated 1878, though it does not appear at what date Part iii was printed, nor at what earlier date it was prepared. He says:

"Gabbro is found in immense masses in Waterville and in the vicinity of Mount Washington. The relationships of its masses to the surrounding strata are not so easily determined as those of the little dikes of diabase and diorite, the walls of which are usually plainly seen; but at some points the rock possesses all the structure of an eruptive mass and when, in other places, this is not found, the evidence furnished by more favorable localities, as well as that furnished by allied rocks in other lands where they have been more thoroughly investigated, must at present be decisive."‡

Dr. Hunt now found occasion to change his position:

"The labradorite rocks in the White Mountains, which had by Hitchcock been referred to norite, are now found by him to be eruptive masses."§

The "porphyritic gneiss" always commanded the attention of

*_Final Report_ II. pp. 214,258,266.

*_Final Report_. II, p. 667.

‡_Final Report New Hampshire_. III. p. 165.

§_Azoic Rocks_, p. 161.

professor Hitchcock. He early published observations as follows:

"The sections given of the common granite, trachytic granite and the Norian series (or at least certain felsites) seem to determine their relative positions, the last being at the top. The brecciated granites of Franconia seem to be older than any of these and to underlie them. * * If these points are assumed, the porphyritic gneiss can be shown to be at the bottom of the series, for it lies outside of the lowest of them."*

In the next annual report the "porphyritic group is described as consisting "mainly of gneiss full of large crystals of orthoclase feldspar, associated with ferruginous and other bands. It is regarded as the oldest of all the formations in the State," for reasons which are enumerated."†

The position of this gneiss is again referred to:

"If the felsite series is of the age of the Upper Laurentian or Labrador of Logan, then by the law of superposition, the strata underneath the common granite are Lower Laurentian. Observation showed us, at this phase in the development of the White Mountain structure, two gneisses and a breccia underneath the granitic sheet. The most important is the "Porphyritic gneiss," or granite sometimes. This is a gneiss having large crystals, usually one and a half inches long, of orthoclase, arranged in layers in the mass, with the longer axes parallel to each other. These we conceive to be the strata.* *

"The descriptions of the Laurentian rocks in Canada and Europe make mention of large quantities of porphyritic gneiss; hence we feel warranted in referring these lower schists to the Laurentian system. We have found nothing older in the state." ‡

Again, in a later discussion of the parallelism of the groups recognized in New Hampshire, having mentioned the Canadian systems, Laurentian, Labrador, Huronian and Cambrian, he says:

"The first two of our groups may be referred to the oldest of these, the Laurentian, without hesitation. We do not possess exhaustive information about the occurrence of this oldest system in other regions. So far as is understood, there are two sorts of associated rocks in its typical localities, one being largely pyroxenic. That variety is wanting in New Hampshire. A porphyritic or *Augen-gneiss* is eminently characteristic of the fundamental rocks in every part of the world; and hence ours may readily be called Laurentian. * * [After correlating succeeding New Hampshire

**Annual Report*, 1871, pp. 25-27.
†*Annual Report*, 1872, p 11.
‡*Proc. Amer. Assoc.*, 1872, xxi, pp. 145-6.

groups, he continues.] The Montalban series are certainly not characteristic of the Laurentian. * * Dr. Hunt is satisfied that they overlie the Huronian or greenstones. Our own observations lead to the view that the typical Montalban rocks underlie the same, as recently stated, though the precise relationship is not beyond controversy." *

I make but two citations further bearing on the structural character and taxonomic disposition of New Hampshire Archæan rocks. The first is connected with the genesis of certain systems :

"If these granites behave like a stratified formation, of course the question is at once raised whether they should not be regarded as true strata. The answer cannot be given from position merely, since it is not uncommon to find sheets of trap or lava holding a perfectly analogous position. We have preferred to think of the White Mountain country, at the end of the Laurentian period, as an immense basin, upon which there was an overflow of common granite. Being liquid it spread itself out like water, assuming a horizontal surface. After a while, there was an eruption of trachytic granite, which spread itself in the same way. Subsequently the felsites were formed above them conformably. It would be natural to regard these granites and felsites as belonging to one period, the Norian. The limits of this system have not been fixed; and it seems as if in New Hampshire, it should commence in the common granite and end with the red orthoclase felsite."†

The second citation is an observation of Mr. Huntington, who says of the porphyritic gneiss :

"The fact that rounded fragments of a dark gneiss are found in the porphyritic, shows that the porphyritic rock in Fitzwilliam is either intrusive, or that in the process of metamorphism, these fragments were not obliterated, and that the dark gneiss — which is very limited, but resembles some varieties of the Bethlehem gneiss — is the older rock." ‡

Reference has been made to the evidence borne on the pages of the Vermont and New Hampshire reports, that the geological disorder reigning in those states is of the most perplexing character. Observations of strike and dip defy co-ordination, except within very limited areas. Many pages are devoted, in different portions of the second volume, to records of dip and strike, but no general tendencies to groups or systems of strikes is distinctly apparent.

*Final Report, ii, 668, 669. See further, pp. 98, 99, 102, 274.

*Proc. Amer. Assoc., 1872, xxi, 145.

*Final Report, ii, 472. See also, pp. 513-514.

I copy at random, for illustration, the records made of the dip of the rocks of the "Montalban series" in a single town, Grafton :

At McKelton's, S. 60° E., 72°.
At mica quarry, N. 32° E., 80°.
At west side, S. 50° E., 75°.
At north, S. 63° E., 70°.
At ¼ mile southeast of J. Martin's, S. 78° E., 70°.
At Alger hill, N. 62° E., 75°.
At H. Bullock's, S. 38° E., 50°.
At Prescott hill, N. 82° E., 40°.
¼ mile northeast of T. Foss', S. 65° E., 70.°
At Mrs. Arvin's, S. 62° E., 78.°
At Tewkesbury pond, S. 33° E., 75.°

Nevertheless, professor Hithchcock has given us, near the close of this volume, a chart of "Principal axial Lines of Vermont and New Hampshire." He says: "This is the final summing up of all the multitudinous observations of this report. * * This map and the statements of the last few pages are the key to Part II. They are the generalizations derived from our entire work, both in the New Hampshire and Vermont surveys."*

Turning to the chart, we observe a series of broadly sinuous lines drawn across the two states, having in western Vermont a general direction nearly north and south; in the eastern part of the state, a general conformity to the trend of the Connecticut river; and in New Hampshire, a still stronger tendency to a NNE direction, with some irregularities in the White Mountain region. These are simply lines of observed structure. We are told also, that at every point, they are the average of the different strikes observed. This is worth something; but geologists will be better satisfied, when, from this multitude of discrete data, some later hand, if not professor Hitchcock's, shall have evolved the deep historic and genetic truth concerning the sequence and vicissitudes of this puzzling complex of terranes.

Thomas Benton Brooks.

1873. The progress of the investigation undertaken by Major Brooks under the auspices of the Geological Survey of Michigan, in 1869, was shaped by complete sympathy with the general views then prevailing; and those, it is just to say, were strictly Canadian. The Canadian survey had settled in the conviction that the iron-bearing rocks of the Marquette region were all of one age, and they were of the same age as the rocks north of lake Huron which they

*Final Report, II, p. 673.

had long known as Huronian. Thus the geologists of Michigan came into the traditional belief that the whole territory of the Northern Peninsula of the state was covered by the Huronian and Laurentian systems—save the recognized Lower Silurian angle at the east—the St. Mary's peninsula. Major Brooks, as the result of four years of investigation, concluded that the whole geology of the Marquette district above the Laurentian, might be embraced in a certain number of groups, which he designated numerically. As the characterization of these groups will be the best exhibit of major Brooks' views, and as these numerical designations are necessary matters of frequent reference among geologists, they will be at once presented.*

XX. *Granites* southwest of Lake Michigamme (Taken from *Wis. Rep.*, iii. 648.

XIX. Grayish-black *Mica-Schist*, often staurolitic, and holding andalusite and garnets, Rarely *chloritic schists.*

XVIII. (Doubtful). *Quartzyte* west end of Lake Michigamme?

XVII. *Anthophyllitic schist*, with iron and manganese.

XVI. (Uncertain.) Contains some hæmatite.

XV. *Argillyte.*

XIV. *Quartzyte*, often conglomeritic. Position immediately over the ore. Contains neither marble, talc nor novaculyte; very rarely argillyte.

XIII. *Specular and magnetic ore.* The principal bed.

XII. Banded, ferruginous, *Jaspery schist.*

XI. Coarse *dioryte*, with a light grayish and reddish feldspar.

X. *Silicious, ferruginous schists.*

IX. *Dioritic rock.*

VIII. Silicious, *magnetic schists.* "Flag-ores."

VII. *Dioritic rock.*

VI. Silicious, magnetic, banded, *chloritic schists.*

V. *Quartzyte*, sometimes containing marble (used as flux) and beds of *argillyte* and *novaculyte.* Very persistent. Very seldom conglomeritic.

IV. *Silicious, ferruginious schist.*

III. *Silicious, ferruginious schist.*

II. *Silicious, ferruginous schist.*

I. *Silicious, ferruginous schist.*

[The crystalline schists follow below.]

"These beds," he says, "appear to be metamorphosed sedimentary strata, having many folds or corrugations, thereby forming in

*The table is compiled from the *Michigan Report*, Vol. 1, pp. 85-116.

the Marquette region, an irregular trough or basin, which, commencing on the shore of Lake Superior, extends west more than forty miles * * While some of the beds present lithological characters so constant that they can be identified wherever seen; others undergo great changes. Marble passes into quartzite, which in turn, graduates into novaculite; diorites almost porphyritic, are the equivalents of soft magnesian schists. * * The total thickness of the whole series in the Marquette region, * * may aggregate 5,000 feet.

"Near the junction of the Huronian and Laurentian systems, in the Marquette region, are several varieties of gneissic rocks, composed in the main of crystalline feldspar, with glassy quartz and much chlorite. Intersecting these are beds of hornblendic schist, argillite and sometimes chloritic schist. These rocks are entirely beneath all the iron beds, seem to contain no useful minerals or ores, and are of uncertain age. No attempt is here made to describe or classify them." (p. 84.)

Of the "diorytes, dioritic schists and related rocks" he says: "These obscurely bedded rocks * * range in structure from very fine-grained or compact (almost aphanitic) to coarsely granular and crystalline, being sometimes porphyritic in character. * * On the one hand it graduates into a heavier, tougher, blacker variety, which is unquestionably hornblende-rock, with some feldspar. * * On the other hand, it passes into a softer, lighter colored rock, of lower specific gravity, which while it has the same streak, weathers similar to true diorite, is eminently schistose in character, splitting easily, and appearing more like chloritic schist than any other rock. (p.99.)

"At several points, dioritic schists, semi-amygdaloidal in character, were observed; and in one instance, the rock had a strong resemblance to a conglomerate." (p. 99.)

"At Republic mountain, a doleritic schist graduates into a black mica-schist," (p. 100). Dr. Hunt expresses the opinion that in the case of Marquette diorites the hornblendic mineral often becomes softened and hydrated, passing into a degenerate form more nearly allied to chlorite or delessite (in which water is an essential constituent) than to a true hornblende." (p. 101.)

"The bedding of the rocks is generally obscure, and in the granular varieties, entirely wanting. It is usually only after a full study of the rock in mass, and after its relations with the under- and overlying beds are fully made out, that one becomes convinced, whatever its origin, it presents in mass, precisely the same pheno-

mena, as regards stratification, as do the accompanying schists and quartzites." (p. 102.)

Of magnesian schists, ("mostly chloritic,") he says:

"Intercalated with the pure and hard mixed ores at all the mines worked in formation XIII, are layers of a soft, schistose rock, of some shade of grayish-green, and often talcy in feeling. * * It is unquestionably a magnesian schist, varying from chloritic to talcose in character, and sometimes apparently containing a large percentage of argillite." (p. 104.)

"A very peculiar occurrence of this rock are the so-called 'slate-dykes,' which can be seen at the New England, Lake Superior and Jackson mines, but still better in the quartzite ridge just north of the outlet of Teal Lake."*

Speaking of the quartzyte (No. XIV,) he says:

"As if to leave in our minds no shadow of doubt as to the sedimentary origin of this rock, nature has, in addition to the conglomerate on the Spurr mountain range, given us a variety of the Upper Quartzite, which can only be described as a fine grained, friable banded sandstone." (p. 108.)

In discussing argillytes, he says, in addition to beds interstratified in the quartzytes:

"At least two distinct beds of argillite have been made out; one immediately beneath the ferruginous schist of formation X, to be seen in outcrop on the south shore of Teal Lake, near west end, and in the rail-road cut about one mile east of Negaunee. Another and far more extensive bed is XV, which forms the stratum next above the upper quartzite. Color usually dark brown or blackish; but where associated with the marble, it is sometimes reddish. It has a true slaty cleavage distinct from the bedding. * * Black, carbonaceous matter is often present." (p. 111.)

"Beyond the limits of the Marquette region, we find in the recently explored Huron Bay District, the finest clay-slates so far discovered in Michigan."† Within the Marquette district, he finds a carbonaceous shale more highly charged with graphitic material, "of a bluish-black color, but burns white before the blow-pipe, marks paper like a piece of charcoal, is soft and brittle, slaty in structure, and having a specific gravity of but 2.06."

"This rock has been found in the Marquette region only at two localities: 1. The S. C. Smith mine, T 45, R 25, where it seems to bound the iron ore formation on the northeast. 2. On the south side of Sec. 9, T. 49, R. 33, along Plumbago brook." Analy-

*See this occurrence described by the writer in *XVI Ann. Rep. Minn.* p. 180.

†This shale is recognized as identical with that occurring west of lake Gogebic.

sis gave professor Brush 20.86 percent carbon. "The analyses prove the material to have no commercial value, but possesses scientific interest as proving the existence of a large amount of carbon in the Huronian rocks. The equivalency of these shales with the members of the Marquette series has not been established; they are undoubtedly Huronian, and are, I suppose, younger than the ore formation XIII." (116.)

Major Brooks reported also, in a condensed way, on the Menominee Iron Range (pp. 157-182,) and very briefly, on the Lake Gogebic and Montreal river Iron Range (pp. 183-6). In connection with the latter, he presents a section showing the unconformable junction of the (so-called) Huronian with the (so-called) Laurentian. This is the same unconformity as has since been pointed out by Sweet, Irving and others.*

1879. Major Brooks, in 1879, made further publication of his views respecting the Menominee region, and particularly, that part of it which extends into Wisconsin.† Of his earlier Michigan work he makes the following memorandum:

"My reconnoissance of the northeastern side of the Menominee, the results of which are given in the Geological Survey of Michigan, vol. I, 1873, gave valuable data; but that work on the whole, was incomplete and crude, and will be superceded by this report, which is, however, not complete in several directions."‡

He recognizes the "Keweenaw (copper series)" among the rocks of his district. The Huronian, he states, is "known to rest nonconformably on the granite and gneissic rocks, regarded as of Laurentian age." [He is here understood to refer to the Penokee unconformity.] As to the Huronian, he claims to have succeeded in determining, in the Menominee region, the equivalents of his numbered groups in the Marquette region; and it will be useful to reproduce the essential parts of his table:

XX. *Granite*, *gneiss* and *porphyryte*.

XIX. *Mica-schist*, *hornblende-schist* and *gneiss*. Black, subcarbonaceous *slate* and *chloritic schists*.

XVIII. (Not observed.)

Trans. Wis. Acad., 1875-6, III, 43-44; *Amer. Jour. Sci.*, 1877, III. xiii, 308. This Whitney and Wadsworth call a "supposed unconformability" (*Bull. Mus. Comp. Zoöl.*, vii, 495, 496, 497), adding that "the proof advanced was, that the foliation of the granite and gneiss dipped at a different angle from that of the Huronian rocks." * * "They have failed to observe the phenomena of contact, when seen, beyond the mere fact of a different dip to the foliation observed." Such too frequent rude contradictions might with more courtesy have given place to expressions of doubt; but, with more justice, to expressions of respect for the authority of such excellent observers.

†*Geology of Wisconsin*, vol. III, Pt. vii, pp. 429-459, with appended microscopical observations by Dr. Arthur Wichmann (of Leipzig), pp. 600-656, and Appendices, pp. 657-663.

‡*Geology of Wisconsin*, iii, p. 431.

XVII. Gray *gneiss* with small crystals of triclinic feldspar, and large ones of orthoclase. Associated with hornblende-chloritic-and micaceous-*quartz-schist*. The Commonwealth Iron horizon.

XVI. Schistose *greenstone*, with micaceous, chloritic, quartzose varieties. *Dioryte* (gabbro?).

XV. (Not identified.)

XIV. Light-gray, specular, conglomeritic *quartz-schist*, containing mica and magnetite.

XIII–VIII. (Not identified.)

VII. Gray and red, soft, unctous, *hydromicaceous schist*, graduating into *clay-slate*.

VI. *Iron ore*. Banded, quartzose, ferruginious *schist*.

V. *Dolomite marble* with cherty laminæ. Very thick and prominent.

IV and III. (Not identified.)

II. Lower *quartzyte*, massive to semi-schistose, arenaceous, in places micaceous and actinolitic, with occasional specular ore. Felch mountain supposed in this horizon.

I. Chloritic *gneiss*; hydrous-magnesian *schist*; *slate-conglomerate*; *quartzyte* and perhaps *dioryte*. (Possibly Laurentian.)

Comparing the Huronian rocks of different regions, Major Brooks reaches the following conclusions:

1. The Huronian rocks are generally rich in species and varieties, but the maximum of varieties is found in the Marquette and Menominee regions."

2. "The points of resemblance between the Marquette, Menominee, Sunday Lake and Penokee series are so numerous as to point, I think, unmistakably to their having been formed in one basin, and under essentially like conditions."

He adds:

"Those who are not disposed to admit that lithology affords much assistance in identifying rock-beds over even small areas, should have in mind that the Lower Silurian sandstone can now be seen quite uniform in character, over a much greater area in the same region. Almost the same remark may be made of the underlying Keweenian rocks. Cannot approximately as favorable conditions have existed for the formation of a particular kind of rock over a smaller area at the earlier period?"*

*Geology of Wisconsin, III, 449-50.

Newton Horace Winchell.

1873. The second season of the Geological survey of Minnesota found professor Winchell engaged in an examination of the geology of the Minnesota river. In describing the outcrops of the "Granites of the Valley," * he noted some features which, in his later researches have proved to possess great significance, the older observers either not having noticed them, or failed to inquire under what conditions they have been produced. This granite is the common ternary variety. In the neighborhood of Granite Falls, he says, in his description, "there are sudden changes in the rock, from real granite to hornblende schist. These occur irregularly." He speaks of the formation as having a dip, and supposes it due to original sedimentation.

1880. The ninth annual report† of the Geological survey of Minnesota contains "A Preliminary List of Rocks," 442 in number, collected by professor Winchell, on a tour made during the season of 1878, from Duluth along the north shore of lake Superior, to Pigeon point, and thence through the interior by the line of lakes and streams marking the international boundary, westward to Vermilion lake, and still thence to the Mississippi river. Both portions of the route had been previously traversed—the line from Grand Portage along the boundary, by Houghton, Norwood, the Canadian geologists, and a long succession of traders; but no previous explorer had gone with so settled a purpose to penetrate the mysteries of the off-shore geology; and no one had made its study the chief end of his visit. Norwood was on a hasty reconnoissance over an extended line; Houghton made a brief excursion as far as to Mountain lake and returned; and Bell passed over the route chiefly for the purpose of reaching the Canadian territories about the Lake of the Woods. The tour of 1878 was somewhat carefully studied, step by step. Not only were rock masses investigated petrographically and structurally, but the plans of the contours of the country, the systems of their building up, the great obvious movements by which juxtapositions and superpositions had been effected—these fundamental phenomena were all taken in by a broad sweep of observation, and the problems connected with them, if not at the time resolved, were placed in the midst of surroundings which continued thereafter to throw important light on them. It is worth the while to note some of the observations made—at the time, apparently isolated, but afterward wrought

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**Second Annual Report of Minnesota*, 1873, pp. 160-176.
†*Ninth Report*, pp. 10-114.

into the great geological conceptions which seem now to represent much of the truth.

On the west side of Grand Portage, slate was seen which was probably the first recognition in Minnesota of the Animike formaion, isolated by Hunt in 1873, and of which so much was to become known. This is subsequently identified as the "silicoargillaceous slate" of Norwood. The "slate and quartzyte of Pigeon River Falls" are said to dip south. Numerous islands off the shore are visited. The principal rock-axis of Pigeon point peninsula, is, he says, "not evidently a dyke, but a massively bedded or coarsely jointed formation which extends west, and soon rises over fifty feet from the water, and shows a basaltic, mountainlike structure. It resembles the rock and structure of Rice point (near Duluth) and may be parallelized with it in age, and here is associated, as there, with a red, metamorphosed rock. Here, however, it is a part of the Animikie beds of Dr. T. Sterry Hunt, which would therefore seem to be only a downward extension of the Cupriferous series."

Proceeding as far as Mountain lake, he remarks "that these hills are all short monoclinals of gray quartzyte, with beds of argillaceous and black slate, dipping uniformly in a southerly direction, and covered with a greater or less thickness of the trap rock (gabbro?) of the country—the trap being sometimes one hundred feet thick, but generally less than fifty feet, and often the only rock seen, the lower beds being hid by the copious *talus*. The slate in some places has a dip slightly southwest, and the inclination amounts, usually, to about 8 or 10 degrees. The trap also dips with the slate, so that the hills have gradual slopes toward the south and steep slopes toward the north, or are perpendicular—indeed, they most frequently are perpendicular for about twenty-five feet from the top, or even one hundred feet, the trap having a widely basaltic structure, which causes it to fall away in perpendicular columns; the slate and quartzyte also, have frequent perpendicular jointage planes, which also facilitate the perpendicular breaking of the beds. The quartzyte is evenly and conspicuously bedded† without any confusion, but alternates, both gradually and suddenly with the black argillaceous slate. The most of it as far as seen to this place, is gray quartzyte. This quartzyte must be an immense formation, as it is that seen at Grand Portage, and all over Pigeon point, and the islands off the point."

Ninth Report, pp 69-70.

†The beds called here "quartzyte" are what the writer, in speaking of these formations, has styled interbeddings of "silicious (often jaspery) schist."

"Several important questions pertaining to the geognosy of this formation arise in an attempt to describe it, which must, for the present, remain unanswered, but which, perhaps, future examinations may solve:

1st. Is this trap older than the uplift of the hills, or did it come over the country when the uplift occurred?

2d. Are the dykes that are seen crossing this trap (as at the foot of South Fowl lake) of the same age as the trap, or are they subsequent to it?

3d. How much of the topography here is due to glaciation?

4th. Do the monoclinal hills run under each other, or are they each separate and isolated uplifts?

5th. Can these beds of supposed igneous rock be due to a change in the sedimentary rocks, instead of igneous outflow?

6th. Why is there an entire absence of amygdaloids?"

Arriving at the north side of Gunflint lake, he notes "hydromica (?) slate." "This rock rises in knolls and hills one above the other, irregularly disposed. The slates stand nearly vertical, running E. 20° N. This passes insensibly into the next," and "graduates back and forth." This resembles some forms of the slate at Thompson on the St. Louis river (p. 82). Belonging to the same formation is a "greenish, porphyritic rock (with albite ?), having an imperfect, schistose and fibrous structure, and some free quartz, embraced much like veins, in the slate. It is not vein matter, but gradually changes to the slate, right and left, the slates standing nearly vertical.

"This outcrop is supposed to belong to what the Canadian geologists have styled the Huronian. It underlies the quartzyte and Gunflint beds [now known as Animike slates] apparently unconformably. At least, it is another and distinct formation from the slates at Grand Portage" (p. 82).

It is to be regretted that this clew was not followed up. This is the discordance which has become celebrated.*

Coming to the characteristic black, silico-argillitic slate which gives name to Knife lake, he styles this rock "a light green, tough magnesian rock [which] can perhaps be designated a chloritic or serpentinous quartzyte," and recognizes it as belonging to the (then called) Huronian slate series; and thus, fourteen years ago, excluding it from the crystalline schist series, to which, later, it has been referred.

1881. A similar journey was made in 1879, and the results are

*Compare also, p. 102 at bottom, and notice the curious speculation, p. 103. It is evident from this that it remains to discover flint and jasper beds in the Kewatin.

found in the report for 1881.* The studies attending this trip were pursued under circumstances promising still larger results. The Knife-lake slates and the schists, now known as Kewatin, were identified near the west end of lake Superior. The tour extended to Grand Marais and Silver Islet, and from Grand Marais to Ogishke Muncie and the mouth of Poplar river. On Mayhew and Loon lakes he examined again, the "great quartzyte and slate formation, or the Animikie group." He describes again, and in more detail, the remarkably flinty breccia on the north side of Gunflint lake, and speculates on the cause of its condition.† I quote the following obscure paragraph:

"The close proximity of this flint and jasper locality to the next great underlying formation (syenites and slates)‡ makes it one of great interest to the geologist, but so far as scrutinized as yet, the true relations of the two formations are not revealed by anything here seen, though there seems to be an unconformability between them." (p. 88.) I have elsewhere quoted this passage as intimating an unconformity between the "slate and quartzyte" and the vertical schists north but further east, on Gunflint lake. But I am not sure this is the author's meaning, because he seems to be comparing the brecciated formation with the (underlying?) slates.

Coming to Ogishke Muncie lake, he subjects the mysterious conglomerate to further investigation. Notwithstanding the length of the passage, it may be well to quote largely, so that the reader may compare the statements with those of Sir William Logan in speaking of the slate conglomerate of Thunder bay (See p. 132.) He says:

"The conglomeritic character is hardly distinguishable on a fresh fracture of the rock, which sometimes shows different shades of green. But all over the surface, when glaciated and weathered, are visible the forms of rounded bowlders included in the rock, the different forms, colors and grain of the bowlders being brought out plainly. This is essentially the same formation as the rock 743 and 737, and it constitutes by far the greatest part of the country rock about Ogishke Muncie lake. Wherein the rock 737 differs from 738, which also passes into 744 by the accession of slaty structure, and the obliteration or modification of it by the accession of bowlders, it may be ascribed to varying proximity to, and influence of, the underlying 'talcose' rocks, in the process of deposition and metamorphism. * * On the island [Campers',]

**Tenth Annual Report Minnesota*, pp. 9-122.

†*Tenth Annual Report Minn.*, p. 87.

‡The breccia locality is *within* the slates of the "Quartzyte and Slate" formation.

it is a real conglomerate, with a smoothly glaciated surface, and the sections of some of the rounded stones are a foot, and even more, in diameter. They are very abundant. Sometimes the rounded stones make three quarters of the whole rock, but in other cases, the slaty matrix is nearly free from them, over considerable areas."

The author suggests the following order of superposition of the rocks in this part of Minnesota:

"1. The nearly horizontal quartzyte and slate formation composing the hills around the Grand Portage and the international boundary as far as Gunflint lake.

"2. The coarse grit or fine conglomerate, No. 738.

"3. The jaspery and calcareous beds that are known as the "Gunflint beds," Nos. 737, 743.

"4. The gray marble, No. 746. [See this further discussed in *XVIth Rep.* pp. 95–6.]

"5. The tilted slaty conglomerate, and the great conglomerate about Ogishke Muncie lake. Nos. 744, 750, 754.

"6. The amphibolyte and the chloritic slates, Nos. 731, 753, 348, 349, 350, 355, 356 and 358.

"7. Mica schists and alternations of mica schists and syenite. Nos. 335, 337, 339, 401, 406, 408, 414, 417.

"8. The syenites and granites of Saganaga and Gull lakes.*

"There is yet," he says, "one very important undetermined question relating to this generalized section, which ought to be borne in mind, viz: Is the great quartzyte and slate formation of the international boundary (No. 1 of this section) the same as the highly tilted slaty and quartzyte formation which passes into the great conglomerate (No. 5)? There are some considerations which seem to imply that it is, though in all descriptions and sections they have been treated as different terranes. (*a*) Where

*I venture to make, on these assignments, the following suggestions:

1. This clearly is the Animike.

2. This, I judge, is only a border condition of the Ogishke Conglomerate (See XVI *Ann. Rep. Minn.* pp. 313, 315). There are also, on the borders of Frog-rock and Town-line lakes, several occurrences of gravelly sericitic schist—as also on Ensign lake. (XVI *Rep.* p. 312, Rock 863; and p. 315, Rock 889, 890.)

3. I feel constrained to regard these as no distinct part of the Animike. (See XVI *Rep.* p. 251.)

4. This is what is described as a bed of dolomyte in XVI *Rep.* p. 316.

5. The Ogishke Conglomerate.

6. By this I understand the author to mean the later-called "Kawasachong rock"—green chloritic slates (even if originally erupted); the "greenstone" hills south and north of Ogishke Muncie, and the chloritic and amphibolitic conditions of the "Kewatin" seen in many places.

No separate place is assigned here to the vertical schists.

These suggestions in a very perplexing inquiry, may be very wide of the mark.

the horizontal slates approach the syenites at the east end of Gunflint lake, there is nothing to be seen of any beds representing the tilted slates. The syenites and their associated schists come on at once. (*b*) Where the tilted slates and conglomerates associated with them are traceable from the syenite upward to the gabbro, as south of Ogishke Muncie lake, there is nothing to be seen of any beds like the horizontal black slates of No. 1. (*c*) The "Gunflint beds" appear to belong to the horizontal slates of the international boundary at Gunflint lake, but their supposed equivalents* at Ogishke Muncie lake belong to schistose and tilted slates and conglomerates. (*d*) Although the horizontal slates and quartzytes of the international boundary strike west and southwest across the state, forming one of the most important topographical features of the northern part of the state, and can be followed for many miles as such, yet they are lost entirely in the region of the upper St. Louis, and the tilted slates are the only ones seen where that river cuts the rock at Knife Falls and below.† (*e*) The great gabbro belt which surmounts the horizontal slates along the international boundary, and prevails to the east and south of their line of strike, is seen to pass to the west of lake Superior, at Duluth, and to disappear from sight suddenly between Duluth and Fond du Lac, as if its continuance depended on the maintenance of the horizontal formation with which it is associated. (*f*) Where the Gunflint beds become jaspery hæmatite, as south and east of Vermilion lake,‡ the structure of the tilted slates passes into the iron ore as if of the same formation. (*g*) The formation which underlies the Cupriferous at Fond du Lac is the tilted slates, and that which underlies it at Grand Portage is the horizontal slates."

"A thorough examination of the hill-range between Gunflint and Ogishke Muncie lakes would probably reveal the facts as to any transition from the horizontal slates to the tilted slates."§

From some confusion noted in the stratification of the region south of Ogishke Muncie lake, the author seems almost ready to adopt the alternative afterward embraced by professor Irving.

In a paper embodying descriptions of fifty thin sections prepared from the rocks of the Cupriferous series of lake Superior professor Winchell pointed out distinctly the two-fold origin of crystalline

*It is not obvious that any such beds are there. But, in any event, if we distinguish the horizontal slates holding the "Gunflint beds" from the vertical slates holding the conglomerate, no difficulty will exist.

†From (*a*), (*b*) and (*d*), it is not to be inferred that two systems do *not* exist, but that they are not co-extensive. Their coëxistence is seen on the north shore of Gunflint lake

‡The very distinct hæmatite formation also contains jaspery beds.

§This journey was made in 1887. See *XVIth Rpeort*, pp. 79-89.

rocks. He showed by demonstrations accompanying the memoir,* that the crystallizations resulting from metamorphism sometimes imitate closely the character and composition of the rocks whose eruptive escape has been the cause of the metamorphism. On the north of lake Superior, the contact of the gabbro with the red sandstone has produced "all stages of metamorphic change — from red sedimentary shale and sandstone to red felsite and syenite." A sedimentary rock heated to the point of fusion of the feldspathic constituents, and then cooled, will exhibit a non-differentiated ground, with feldspar crystals porphyritically disseminated. Heated completely to the fusing point and then cooled, the least fusible mineral — probably quartz, would first crystallize out, and later crystallizations would be penetrated by the older quartz. Simultaneously, the intrusive matter would impart certain constituents to the softened sedimentary bed, and minerals would arise for which the requisite constituents had not before existed in the bed.†

1884. At the Philadelphia Meeting of the American Association, he delivered an address before the Section of Geology as its president in which he discussed "The Crystalline Rocks of the Northwest."‡ This was a broad survey in which he attempted to arrange the succession of the great Archæan terranes, and point out their relations according to the views of other geologists. As the table at the end contains a convenient synopsis of the positions taken that will be here first introduced.

**Proc. Amer. Assoc.*, 1881, XXX, 160-6. Also *Tenth Ann. Rep. Geol. Minn.*, pp. 137-143. The subject was earlier discussed in *Proc. Amer. Assoc.*, 1880, XXIX, pp. 422-425. Comp. also, Tenth Rep., pp. 108, 111.

†The phenomena here referred to are of the same character as those which professor Bailey has since described and explained. See *Amer. Jour. Sci.*, III, xxxix, 273-280, Apr. 1890.

‡*Proc. Amer. Assoc.*, 1885, Pt. II, pp. 363-379; *XIIIth Minn. Report*, pp. 124-139; *Amer. Naturalist*, xviii, 984-1,000, 1884; *Science*, iv, 230-240, Sep. 12, 1884 (abbreviated.)

GROUPS.	EMMONS.	HUNT.	BROOKS.	IRVING.	Equivalents in Michigan.	Equivalents in Wisconsin.	Equivalents in Minnesota.
GROUP I. Granite and Syenite with Gabbro.	Hypersthene Rock. (Regarded as part of the Primary.)	MONTALBAN. Labradorian. Norian Upper Laurentian, Aronian.	Youngest Huronian.	Base of the Keweenawan.	XX	I and Ia. at Black River.	Duluth. Brulé Mountain, Misquah Hills, Beaver Bay.
GROUP II. Mica Schist.		MONTALBAN.	The	The	XIX at Marquette. XVII—XIX at Menominee.	XX—XXII at Penokee.	Little Falls. Pike Rapids. Outlet of Vermilion Lake.
GROUP III. Carbonaceous and Arenaceous Black Slate.	TACONIC SYSTEM. 1842–1846. Black Slate.	Animike.	Huronian	Huronian	XIV—XVII at Marquette. XV and XVI at Menominee.	VI—XVI at Penokee.	Animike. Black Slates, Grand Portage.
GROUP IV. Hydromica and Magnesian Slate.	Taconic Slate.		of Brooks.	of Irving.	VI—XIV at Marquette. VI—XI at Menominee.	IV—VI at Penokee.	At "The Mission" Vermilion Lake, Vermilion Iron Mines.
GROUP V. Quartzyte and Marble.	Stockbridge Marble. Granular Quartz Rock.	The Huronian of Canada, 1855.	1873.	1879.	V at Marquette. II—V at Menominee.	I—III at Penokee.	Ogishke Muncie Lake.
GROUP VI. Granite and Gneiss with Hornblendic Gneiss.	Primary.	Laurentian.	Laurentian.	Laurentian.	Laurentian.	Laurentian.	Laurentian.

The author of this table comments upon his "Groups," in substance, as follows:

FIRST GROUP. Is represented in Minnesota by the gabbro and red syenite at Duluth. * * The outcrop of red granite near New Ulm, lying under the conglomerate and red quartzyte, is probably in the southwestward line of extension of this group.

SECOND GROUP. Consists of schists that are micaceous and often staurolitic as well as garnetiferous. Variously associated with beds and veins of granite and gneiss. Has a maximum thickness of 5,000 feet.

THIRD GROUP. Sometimes passes into roofing slates, with beds of iron ore, quartzyte and dioryte. "Includes the black slates of the Animike group in northern Minnesota, of Knife lake, Knife Portage on the St. Louis river; and carbonaceous shales lately reported near Aitkin on the Mississippi river. Thickness, 2,600 feet.

FOURTH GROUP. Schists soft and obscure, becoming quartzose and also hæmatitic; also with numerous beds of dioryte. In Minnesota, this is the iron-bearing horizon at Vermilion lake. Maximum thickness, 4,450 feet.

FIFTH GROUP. Represented by No. V. at Marquette, Nos. II. and V. at Menominee, and Nos. I. and III. at Penokee. The marble lies above the quartzyte, and in the Menominee region has a minimum thickness of 1,000 feet; while at Marquette, it graduates into a dolomitic quartzyte of indefinite extent, the whole group being there essentially quartzyte. A most persistent and well-marked horizon. The quartzyte sometimes holds feldspar, thus having the appearance of granulyte. In Minnesota this horizon seems to run along the south side of Ogishke Muncie lake, near the international boundary, and includes perhaps the great slate conglomerate which is there represented. This seems to correspond to the lower portion of the great quartzyte of this group, and to be the equivalent of the "lower slate-conglomerate" of the typical Huronian in Canada. Normal thickness from 400 to 1,000 feet; but if the great conglomerate of Ogishke Muncie be included here, the thickness of this group in northern Minnesota will exceed 6,000 feet.

SIXTH GROUP. In Minnesota, found on the international boundary, at Saganaga lake, and large boulders from it are included in the overlying conglomerate at Ogishke Muncie lake, showing an important break in the stratigraphy. Thickness unknown, but very great.

In the progress of the discussion, the author proposes to install the term "Taconic" in the nomenclature of the older rocks.

1887. The report of this year embodied views evincing positive progress in reference to several questions. The intimate relations of granitic rocks with terranes of admissibly sedimentary origin were brought into distinct view, and many instances of transition were pointed out,* and many remarkable cases of inclusion of granitic and gneissic fragments in the body of the schists, and vice versa. In the report, it was intimated that the Animike formation overlay one eruptive rock and underlay the other, and that it seemed to embrace the Ogishke Conglomerate in its lower portion (p. 381). The lower eruptive rock was represented to be, in some places, a remarkable agglomerate, and in various ways, to become changed to greenish schists, chloritic and sericitic, and to embrace in its mass, generally with an appearance of unconformity, the jaspilyte and iron ore of the Vermilion lake region. At the same time, this green rock exhibited, at times very manifestly, some signs of aqueous stratification. At other times, no such structure was found in it, and it merged into a dense, homogeneous, unbedded, doleritic mass. It was announced that the graywackes, which are in this "green-stone" formation, fade out by merging into its evidently eruptive condition; but in many places are distinctly sedimentary, having much quartz in rounded grains, arranged in unmistakable layers.

It was again pointed out that besides the large body of normal gneiss at the geological base of the series, there is inseparably associated with the gabbro, a red formation, having the apparent composition of syenite; and also a further distinction in the rock of the Giant's range — one portion of it being the result of local change in some bedded sediments probably later than the Laurentian (pp. 347, 349, 352, 353). The cause of this change in the sedimentaries was suggested to be the gabbro eruption. The red syenite resulting is the "red rock" of the earlier reports, the red quartz porphyry and the "Palisade rock" of lake Superior shore. This report contains a geological map of the northeastern part of Minnesota. The distinctions recognized are the following:

1.	Trap and amygdaloid	Cupriferous.
2.	Feldspathic sandrock	
3.	Gabbro and red granite, sometimes dioryte	Mesabi range.
4.	Quartz porphyry and felsyte.	

**Fifteenth Annual Report Minn.*, 1887, pp. 290, 292, 293, 294, 296. See also, the accompanying reports.

5.	Gray quartzyte and black slate	Animike.
6.	Greenstone, diabase and chlorite schist.	
7.	Sericitic schist, argillyte and graywacke	Kewatin (in part.)
8.	Iron ore.	
9.	Conglomerate and conglomeritic felsyte	Ogishke.
10.	Mica and hornblende schist with dioryte	Vermilion series.
11.	Gneiss, syenite, granite	Laurentian?

1888. Questions of taxonomy and parallelism occupy much attention in the report of work for 1887.* A visit to the "Original Huronian" of Sir William Logan leads to the conclusion that while the stratigraphic descriptions of Logan were faithful, the "green chloritic slates," so-called, are not by any means constituent parts of the stratigraphy, but are distinctly eruptive. The "slate conglomerate" of Logan, he thinks repeated in Minnesota, in the Ogishke Conglomerate (pp. 39, 58, 59.) The general parallelism is given as below.

CANADA.	MINNESOTA.
Ottertail quartzyte, Thessalon quartzyte	Pewabic quartzyte? New Ulm, Pokegama and Wauswaugoing quartzytes.
Black slate	Animike black slate.
"Lithographic stone" and fine gray quartzyte	(Not known.)
Red felsyte	Felsytes at Duluth, and probably the great Palisades.
Missisagui quartzyte	(Not known.)
Slate conglomerate	Ogishke conglomerate.

Careful observations reported from the region north of Gunflint lake, indicate two conclusions:

1. There is a gradual transition, structural and mineralogical, from the Kewatin downward, through mica and hornblende schist, to the gneiss (pp. 68-70. Also *XVI Rep.*, 37-39.)

2. The intermediate crystalline schists (Vermilion group) do not seem in all places to be present (pp. 74-77, 81.) Room exists for the supposition that the metamorphic action in some regions was sufficiently powerful to carry fused masses of the lower sedimentary rocks bodily across the stratigraphic horizon of the crystalline schists into contact with the Kewatin schists. For this reason, crystalline schists sometimes are interrupted by gneissic rocks.

Of conglomerates in crystalline horizons, he says:

**Sixteenth Minnesota Report*, 1888.

"The conglomeritic structure has therefore now been seen in the following crystalline rocks of Minnesota:

1. The Sauk Rapids "granite."

2. The porphyritic conglomerate at Ogishke Muncie lake, and the similar gneiss in Kekekabic lake.

3. The Stuntz island porodyte.

4. The greenstone of Twin mountain.

5. My brother reports it conspicuous in the Saganaga gneiss.

6. This bowlder [from Iron lake] shows it in the Vermilion group. (Later known in gneiss at Redwood Falls and Morton in the Minnesota valley.)

7. In the Laurentian syenite in Michigan, south of the Aurora mine.*

As to the distinctness of the Animike and Kewatin, the author entertains no longer any doubts, and he cites facts on pages 80 and 81 which prove it, and prove the equivalence of the Huronian of Canada with the Animike. But the upper part of the Ogishke conglomerate he is disposed to regard as a member of the Animike

In traversing the country between Gunflint lake and Ogishke Muncie lake he established the existence of an upper member of the Animike, which was named Pewabic quartzyte. It is magnetitic, and lies near the top of the Animike (pp. 85-86.) He parallelizes the Pewabic quartzyte with:

Wauswaugoning quartzyte.

Thessalon and Ottertail quartzyte (of Ontario.)

Potsdam sandstone of the Adirondacks.†

And these are regarded as further equivalents of the Pewabic quartzyte:

Granular quartz (Emmons)

Teal lake quartzyte, No. III (Brooks.)

Quartzyte group (Rominger.)

Baraboo quartzyte.

Sioux quartzyte (See XVIIth. Minn. Rep., p. 51‡.)

The following is the method of reasoning employed to establish the relations of the Ogishke conglomerate with the Animike:

"The hills about the northeast extremity of Gabimichigama lake consist entirely of Animike, fine-grained, tilted, fractured, rece-

*Many bowlders may be seen in the granite of which the Chicago "Auditorium" is built. According to the writer's observation, few granites can be found without evidence of fragmental intermixture. The granite in the "Auditorium" was taken from the Giant's range, at Hinsdale, Minn.

†On this parallelism see, also, *American Geologist*, March, 1890.

‡In the eighteenth annual report he concludes that the Pewabic quartzyte is below the black slates of the Animike, carrying with it the great gabbro outflow and the red granites and quartz porphyries to the same stratigraphic position.

mented, but in general dipping northeasterly. At the lake shore, these beds weather out very rough, the silicious veins and the harder beds projecting. In some places they are about vertical, but they vary constantly in dip and strike."

"In passing along the north shore westward, however, N. E. ¼ of sec. 31, 65-5, this rock becomes slaty and vertical, and strikes N. W. by compass.

"All along the north shore, from the northeast end of the lake to about the centre of N. E. of sec. 31, 65-5, these titled slates and quartzytes extend, having a high dip toward the northeast, and finally becoming vertical. The shore-line runs across the strike but not at a right angle. Hence in going west, one passes onto lower and lower beds. At this place the Ogishke conglomerate appears on the shore, rising in a ridge about fifty feet high, at a few rods from the shore. On the beach it is disintegrated and hardly preceptible. The dip of the beds of quartzyte and slate that are interbedded with it is 88° N. E. and the strike N. W. *There is thus seen to be an undeniable graduation from the Animike into the Conglomerate.*" (pp. 90-91).

Further evidences of a transition are thought to be present in the disturbed condition of the strata about Fox and Agamok lakes (pp 94-95).

1889. This result, as announced above, is pronounced in the report of work for 1888* an important point reached—"the separation of the Ogishke conglomerate from the greenstone agglomerate, on which in some places it must lie unconformably. They seem to have both been affected by the gabbro epoch of disturbance and the gabbro was found in different localities to lie on the greatly inclined strata of one, and the nearly vertical strata of the other."

This report embraces very comprehensive discussions of the "parallels of the Kewatin," the "possibility of rocks younger than the Kewatin, before the beginning of the Taconic," the "age of the Taconic (Animike Huronian)," and the "age of the Potsdam," all of which must be consulted in arriving at an adequate estimate of aggregate results reached by the author; but it is necessary here to avoid prolixity. Among "problems that need further investigation," the following themes are suggested: Eruptive and sedimentary Laurentian; Planes of hydrothermal fusion, and their relation to the origin of the crystalline rocks; Date of upheaval of the crystalline schists; Nature and origin of jaspilyte; What is muscovado rock ?

**Seventeenth Annual Report, Minnesota,* p. 24. 1888.

Toward the close of the report, the following general table of Minnesota rocks is introduced:

CALCIFEROUS. Magnesian limestones and sandstones. ST. CROIX. Sandstones and shales.	Dikelocephalus horizon.
Overlap unconformity.	
POTSDAM. Quartzyte, gabbro, red granite and Keweenawan.	Paradoxides horizon.
Overlap unconformity.	
TACONIC. Black and gray slates and quartzytes, iron ore (Huronian, Animike).	Olenellus horizon.
Overlap unconformity.	
KEWATIN. (Including the Kawishiwin or greenstone belt, with its jaspilyte), Sericitic schists and graywackes. VERMILION. (Coutchiching?) crystalline schists.	Archæan.
Eruptive unconformity.	
LAURENTIAN. Gneiss.	

CARL ROMINGER.

Dr. Rominger's observations and speculative opinions in reference to the older rocks are embodied in a state report upon the Marquette and Menominee iron regions of the Upper Peninsula of Michigan.* Taking up first the Marquette iron district, he conceives it "as a synclinal trough of granite, which by the upheaval of its northern and southern margins, caused the inclosure of the incumbent sedimentary strata between its walls, and their simultaneous uplift and corrugation into parallel folds by the lateral pressure exerted from its rising and approaching edges" (p. 4).

Speaking more specifically, he says of the two series hitherto regarded as Laurentian and Huronian :

By comparing the descriptions of the Laurentian formation as developed in Canada, with the granitic exposures observable in Michigan, or specially in the Marquette district, I cannot see so strong an analogy between them as to identify them without hesitation ; while I endorse the identification of the other group of rocks with the Huronian, although they differ too, in some degree" (p. 5). "I declare at once my serious doubts whether the granites of the Marquette region represent the Laurentian series of Eastern

*Geological Survey of Michigan, Upper Peninsula, 1878–80, accompanied by a Geological Map. vol. iv, 8vo., pp. 248, 1881.

Canada, which I have never had an opportunity to study in the field, but which is represented to be a much older formation, pre-existing as the surface rock before the Huronian sediments began to form, while, according to my own observations, the granites of Marquette are eruptive masses, which came to the surface after the Huronian beds were already formed."

Referring to the discordances between these two systems, frequently alleged by the Canadian geologists, he says:

"As far as my observations go, I have never been able to discover any positive proof of an existing discordance."

Further, in reference to the successional and structural relations of the series, he continues:

"By their eruption, [the granitic rocks] caused not only the great dislocations of the Huronian formation, but the half molten, plastic granite mass induced by their contact with the Huronian rock-beds, also their alteration into a more or less perfect crystalline condition, and commingled with them so as to make it an embarassing task to find a line of demarkation between the intrusive and the intruded rock-masses. The syenitic and gneissic hornblende rocks connected with the granite differ so little from the crystalline hornblende rocks of the Huronian series, that I look at them merely as differently advanced stages in the transformation of the same material. Those nearest to the focus of altering influences are now completely transformed and restored to the domain of the volcanic nucleus; the more remote strata were less changed, and retained distinct marks of their sedimentary origin; but if this view is correct, it cannot be expected to find traces preserved of the conformable or non-conformable deposition of the Huronian layers on their substratum" (pp. 6, 7).

He dissents from the subdivisions of major Brooks.

"Beginning below with his groups from I to V, he never made an attempt to define them. * * As to groups VII, IX and XI, certain dioritic outcrops are designated and considered to be regularly interstratified layers in the sedimentary succession, while I have full reason to consider them as intrusive masses, belonging to a lower horizon of the Huronian series, which by volcanic pressure have been forced through or between the incumbent rock-beds wherever a chance for it was offered, and consequently are found, one time in contiguity with this, another time with another stratum as it happened to be the surface rock of the spot. * * Groups XV to XX, intended to comprise a younger series of beds developed in the western part of the Marquette region, are unnecessarily multiplied into vaguely defined subdivisions. Major Brooks iden-

tified strata of the Menominee river district as representatives of Groups XV to XX which, lithologically, have no similarity with those of the Marquette district, adding still more to the confusion already existing." Dr. Rominger arranges the Huronian series in the following subdivisions (p. 8).

VI.	Mica Schist Group.	
V.	Arenaceous Slate Group.	
IV.	Iron Group.	[Quartzite Group (p. 71.)]
III.	Quartzite Group.	[Iron Group.]
II.	Dioritic Group.	
I.	Granitic Group.	

The Serpentine group is separately considered.

Before the completion of his report, Dr. Rominger became convinced that his Iron group and Quartzite group ought to exchange places, as shown above in brackets.

Besides the granitic masses bounding the Huronian on the north and south, he says:

"Granites are also found interstraified with the Huronian schists."

Of the character of the granite he says:

"They are usually middling coarse grained, of reddish tints, often composed of a magma of incompletely defined crystals imbedded within a granular interstitial mass rather than of well-formed, completely defined crystals; its fracture is therefore rather generally of a dull lustre. * * The micaceous constituent of these granites, where it does enter into the composition, is rarely well crystallized in brightly shining larger leaves, although it occurs occasionally, but usually has a minutely scaly form and a dark green color approaching to chlorite by gradations, or is replaced by hydromicaceous, fibrous, granular substance, generally called talcose from its soft greasy feel and its lighter color, with partial transparency in thin seams" (p. 15).

In describing gneissoid rocks of this region he says:

"This stratified banded rock, in contiguity with the granite, and alternating with it in parallel belts, often becomes completely entangled with it. The granitic masses intersect the gneissoid, enter wedge-like between them in the direction of the lamination or transversely, inclosing strips of the gneissoid ledges between the loops of the anastomosing granite seams, and, moreover frequently the so intermingled masses are curved into the most curious coils and serpentine flexions, which evinces their almost plastic condition at the time their intermixture took place." (pp. 16, 17.)

Passing to the consideration of the Dioritic group, and repeating his conviction that the granites are the newer, he says:

"One may ask, of what nature, then, was the substratum on which the Huronian sediments were deposited? I answer: Nothing contradicts the possibility of their deposition on a surface of granite already formed; it is even probable to me that it has been so; but, if we reflect upon the high degree of plasticity, and the almost perfect liquefaction which the concerned rocks subsequently underwent, and upon the dislocative forces causing the softened, and necessarily by this softening process, considerably altered, masses to intermingle almost chaotically, we can no more wonder that the traces of the originally existing former relative position of the rocks among themselves are greatly obliterated. The records of these periods in the history of the earth's crust, when oceanic sediments commenced to form, and fell back again within the grasp of the central fire-focus, as we can observe it in this case, are wiped out, and most likely all our efforts to ascertain the existing original conformity or discordance between such rocks will be in vain" (pp. 22, 23).

"The rock series comprised under the name of *Diorite Group* is made up by a large succession of schistose beds of a very uniform character, which are interstratified with massive belts of diorite differing in structure from the minutely granular, almost aphanitic condition, to a coarsely crystalline form, and being in chemical composition almost identical with the schistose beds" (p. 23).

Certain relations of the dioritic masses and contiguous schists are of interest:

"Often we see, as in the above mentioned instances, the schists adjoining a diorite mass completely entangled with it, in a mode which proves a high degree of plasticity of the diorite mass at the time intermixture took place. * * Although the general character of this large series of rock-beds is very uniform, as it regards the chemical composition, still, an endless number of variations in their structure is produced by the different degrees of metamorphism to which these once indubitably sedimentary rock-beds were subjected" (p. 34).

It will be remembered that major Brooks had admitted the existence of two horizons of iron ore. This was because at Negaunee and the vicinity, a quartzyte was found in a relation of infraposition to the ore-bed, while in most of the mines of the district, a quartzyte was seen reposing above the local ore-bed. These phenomena were supposed to indicate the existence of an ore-bearing

horizon above the quartzyte and another below it. Dr. Rominger undertakes to prove that only one ore-horizon exists, and that the normal position of the quartzyte is above. Major Brooks was also under the necessity of assuming two quartzytes, Nos. XIV and V, the latter, or Teal lake quartzyte, being, according to Rominger, identical with the former, and its actual relative position being "the result of an overturn of the strata." (pp. 71, 72, 89.)

Lithologically, he adds:

"The quartzites covering the ore-bearing ledges are compact, dark-colored by hæmatitic pigment and by intermingled granules of martite. The inferior strata are almost regularly brecciated and intermingled with ore-fragments. In the pits of the Cleveland mine, south of the Houghton and Ontonagon Railroad, these brecciated quartzites are immediately underlaid by a fine seam of specular ore which itself, is on its surface, of brecciated structure. This ore-bed is underlaid by a series of light greenish or grayish colored, silky-shining, hydromicaceous schists impregnated with small martite crystals, which on their part, repose on the red, jasper-banded lean ores with inclosed seams of granular and slaty specular ore. In the pits north of the railroad, the quartzite is generally underlaid by chloritic schists inclosing locally quite large octahedrons of martite. Below them usually follows a valuable seam of specular ore, schistose chloritic beds again, and then mixed, jasper-banded, lean ores, with other interstratified seams of ore, partly in the granular form, partly as a slate-ore; lowest, resting on dioritic schists are, in the New York mines, fine-grained, silky-shining, dark, gray-colored argillites, charged with minute granules of martite more or less abundantly," (pp. 81-82).

The "*Arenaceous Slate Group*" of Rominger is generally incumbent on the quartzyte formation; but where this is wanting, it rests on the iron ore formation; and if this also is absent, it rests directly on the dioritic series. According to these statements a break exists between the epoch of the quartzyte and that of the Arenaceous Slate (Compare also, pp. 113, 114, 115.) These strata appear sometimes as "a thick belt of black, fine-grained, slaty rock-beds, interlaminated with silicious sandy seams. * * Next south of these slates are high walls of massive, light colored quartzites in direct conformable contact with them," (p. 105).

In other localities, the group "consists of sandy, somewhat micaceous flagstones, or of finer-grained, banded, silicious rock-beds all more or less impregnated with protoxide of iron as a coloring-matter, and with granules of magnetite, (p. 108). Elsewhere they are clay-slates more or less silicious, (pp. 112, 113); or "black

magnetic flags interlaminated with slaty and arenaceous seams," (p. 117).

At a locality in the valley of the Carp river this series has "in part, a conformable northern dip with the quartzites, but frequently also, a southern dip is observed; though the direct contact of the two formations" is concealed by Drift, (p. 106).

This Arenaceous Slate group occupies the surface over a large area on the north of the dioritic belt which abuts on lake Superior at Marquette; and over another area on the south of the dioritic belt. It is believed by Dr. Rominger to be of the same age as the slate formation in the district of L'Anse and Huron bay, between Marquette and Keweenaw point. *The thickness of the latter slates "is enormously great." In color they range from dark to blackish, are partly hard and silicious, of bedding and cleavage too irregular for roofing, but are also in part, regularly laminated, of an agreeable black color, and well suited for roofing, (vol. iii, p. 163). Locally, however, the Huron slates vary to "whitish-gray-yellow, red and brown." They possess all degrees of hardness. The cleavage appears often coincident with the sedimentation, but where the colored bands are preserved, they are seen to make an acute angle with the cleavage. The sedimentary dip is northward. The formation presents three divisions: An *upper* of lighter colored, variegated slates; a *middle*, of alternating slaty and arenaceous beds, with interstratified, larger, compact quartzyte belts of light color and partly blackish; and a *lower* division embracing the roofing-slates, (vol. iv, p. 130). The middle division is regarded as equivalent to the Arenaceous Slate group of the Marquette district. It is likewise an instructive coincidence that a higher horizon of iron-ore occurs in both regions, of which the Taylor mine is an example in the L'Anse district, and the Northampton and d'Alaby mines (north of the Champion mine) are examples within the Marquette district. The ore occurs above the black slates, which in the Marquette district are graphitic. These ore deposits are regarded as contemporaneous with that of the Commonwealth mine in Wisconsin† (pp. 130, 222-227).

The rocks of the Mica Schist group of Rominger are described as "a sub-porous ground-mass of very minute granules of white, translucid quartz in intermixture with a large proportion of bright-

*Dr. Rominger's earliest observations on the L'Anse slates are found in *Geology of Michigan*, vol. iii, pp. 159-166. His later views are in vol. iv, pp. 129-130.

†This is the view of major Brooks, recorded ante' p 174. The reader cannot fail to compare the description of these slates and their accompaniments of quartz-schist and iron-ore, with the published descriptions of the Animike series. See, especially, ante' pp. 176-184. For further description of the Commonwealth mine, see C. E. Wright, *Geology of Wisconsin*, vol. iii, pp. 678-684. Compare also, Eagle mine, Wisconsin.

ly glistening black mica scales, and not rarely also, with chlorite" (p. 131).

The mica is sometimes silvery, and the schists are interlaminated with large belts of a more compact, minutely granular, sub-porous quartz rock, not so rich in the micaceous constituent, but often mingled with curved greenish crystals of actinolite.* In some conditions this formation reveals a distinct sedimentary striation (pp. 132, 133).

Dr. Rominger is not able to reach a satisfactory solution of the genesis of the Serpentine group.

"The hypothesis that the Serpentine formation is the product of local metamorphic influences on the dioritic series [by which it is surrounded], is very improbable, as the lithological character of the two contiguous rock-species changes abruptly." "The rocks occur generally in bulky, non-stratified masses which, if they ever originated from mechanical sedimentary deposits, are by chemical action so completely transformed as to efface all traces of their former detrital structure. They resemble a volcanic eruptive rock, forced to the surface in a soft plastic condition; and most likely heat was one of the prime agents in their formation, or else transformation in combination with aqueous vapors—which is suggested by the hydrated composition of the serpentine" (p. 135).

A study of the Menominee iron district led to the determination of the following groups of rocks (p. 182).

III. *Lake Hanbury Slate Group.* Dark-gray, slaty or schistose beds, with interlaminated quartzose belts. Thickness over 2,000 feet.

II. *Quinnesec Ore Formation.* In the *upper* part, light red, whitish or gray, hydromicaceous and argillitic strata. In the *lower* part, silicious beds richly impregnated with iron oxide in the amorphous, hæmatitic condition, or in the crystalline form of martite, with metallic lustre, and inclosing beds almost exclusively of martite granules. The valuable ore deposits. 1,000 feet.

I. *Norway Limestone Belt.* Light-colored quartzyte and silicious limestone, usually in part of a brecciated structure. 1,000 feet.

The rocks along the Menominee river are regarded as equivalents of the Diorite Group of the Marquette district, and decidedly *not* representatives of Nos. XV–XX of major Brooks.

*Evidently this is not a proper "mica schist," but rather a micaceous quartzyte or a micaceous quartz schist. It can scarcely be compared with the "tender" mica schists of Hunt's Montalban, though the horizon is nearly coincident.

In general, the comparison of the Marquette and Menominee districts, in spite of Dr. Rominger's deprecation of tabular parallels, may be best shown by the following table (pp. 240-241):

	Marquette.	Menominee.
V.	Ore deposits of the Taylor, S. C. Smith, d'Alaby and Northampton mines. Actinolite schists above quartzytes of Michigammi and Spurr mines.	Commonwealth and related ores. Actinolite schists.
IV.	Quartzyte Group (Teal lake). Limestone in juxtaposition.	Quartzyte of Sturgeon river falls. Limestone separated by an interval.
III.	Iron Group.	Quinnesec Iron range.
II.	Dioritic Group. Intrusive Granites.	Diorytes and schists of Menominee river. Felsyte Porphyry, Pemenee Falls.

Roland Duer Irving.

1877. In his annual report for 1874, made to Dr. I. A. Lapham, state geologist of Wisconsin,* the "Copper-bearing Rocks" were made by professor Irving, a distinct division in the geology of the northern part of the state, holding a position between the Huronian and the Potsdam sandstone. He showed also the existence of a synclinal axis in Wisconsin, in continuation of the great trough between Keweenaw point and Ile Royale.† He held, *first*, that the beds of the Copper-bearing series and those of the Huronian were once spread horizontally over one another, including the whole series of tilted sandstones on the Montreal river; they were disturbed by the same force, and receiving their present tilted positions at the same time, as evinced by the entire conformability of the two series. *Second*. The horizontal sandstones of the Apostle islands and the west side of lake Superior were laid down subsequently, and after an immense amount of erosion; and the sandstones of eastern lake Superior were formed at the same time. *Third*. The Copper-bearing rocks should rather be classed with the Archæan than with the Silurian.

The Baraboo and related quartzyte masses lying in Wisconsin, many miles south of the principal Archæan area, have been differently viewed by different geologists, some regarding them as of Huronian age,‡ and others, as the representatives of the Potsdam sandstone,§—the Wisconsin sandstone so described, pertaining as

***Geology of Wisconsin*, Survey of 1873-1877, vol. ii, p. 47, 1877.

†This view was earlier set forth in *Amer. Jour. Sci.*, III, viii, 45-56, 1874.

‡J. Hall, *Geology of Wisconsin*, 1862; Irving, *Amer. Jour. Sci.*, III, iii, 93-99; *Geology of Wisconsin*, ii, 504-524; Chamberlin. *Geol. Wis.* ii, 248-256.

§Percival, *Annual Report Geol. Surv. Wis.*, 1856. p. 101; A. Winchell. *Amer. Jour. Sci.*, II xxxvii, 226; J. H. Eaton, *Wiscon. Acad. Sci.*, Feb. 1871.

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they think, to a higher horizon. Professor Irving, as early as 1871, announced his conviction of their Huronian age; and in the Wisconsin report, he worked out the evidences with fullness. The quartzytes are differentiated from the contiguous sandstone by lithological characters and abrupt structural unconformability; and the only weakness in professor Irving's position is the lack of full proof that the sandstone is the true equivalent of the Potsdam.*

1880. The third volume of the geology of Wisconsin reveals his masterly grasp of the geological structure of northern Wisconsin, and of the genesis and history of the rocks which underlie the region. Here are presented in bold and confident outline, those interpretations, bordering sometimes on speculation, which characterized the leading discussions which occupied him until removed by an early death. His writings are so voluminous, however, that it will not be practicable to do more than set forth his positions on some of the great questions with which he grappled.

In reference to the nature and origin of the Laurentian rocks, which he fully parallelized with the Canadian Laurentian (iii, 5), we find him using the following language:

"The prevailing rock along the northern border [of the northern mass] is a dark gray to black hornblende gneiss, in which the hornblende has usually been more or less altered to chlorite. This alteration, when carried to any considerable extent, gives a greenish tinge and greasy feeling to the rock, and in cases of extreme alteration, there is a passage to a green chloritic schist. The associated granites are usually light pinkish-tinted to gray, and highly quartzose, a frequent gneissoid tendency showing their sedimentary nature," (iii, 6).

"The hornblende gneiss is always very plainly laminated, frequently highly schistose and the whole internal structure of the rock, as seen under the microscope, shows conclusively its original clastic condition. The granites are generally without such distinct bedding but appear nevertheless, to be true metamorphic granite. No eruptive granite, recognizable as such, has been observed. It is not possible, without overstepping the limits of our district, to reach any important generalizations with regard to the Laurentian series. It is evident enough that the rocks are of a true sedimentary origin, and that they have been folded in an exceedingly intricate manner," (iii, 93).

In still another place, professor Irving records views in this connection, which possess interest:

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*This equivalency has been earnestly contested in writings by N. H. Winchell, already quoted. See. anté, pp. 175.

"The term igneous, as used by Mr. Wright, who seems also to hold to the unwarrantable theory that the original rock of the earth's first formed crust would be granite, is one not applicable to any granites, since even in the case of the exotic kinds, the relation of the constituent minerals disproves a true igneous origin. The quartz of granite is always the last formed mineral, whereas, from its infusibility, it would certainly be the first to form in cooling from a state of fluidity. All the facts go to show that the intrusive granites are but sediments softened by what has been termed aqueo-igneous fusion, to a degree of plasticity sufficient to allow of their penetrating fissures in the adjacent formations. The intrusive or exotic granites and the metamorphic or indigenous granites have thus had about the same origin, and there are no lithological characteristics whatever, either microscropic or macroscopic, by which we can distinguish them in specimens," (iii, p. 194, note).

At a later date, professor Irving recorded his views as follows:

"This stratification [of gneiss], or parallel arrangement of its ingredients, is commonly believed to have been caused by the process of sedimentation, the crystalline texture now shown by the gneiss and all other crystalline schists being regarded as the result of a peculiar process of molecular arrangement known to geologists as 'metamorphism.' While it seems very probable that there is a great deal of truth in this view, the theories of metamorphism as they now stand, are very unsatisfactory. Many rocks which have been called metamorphic are plainly of an eruptive origin, and it seems not improbable that the same origin is to be attributed to some rocks with a strongly developed schistose structure." *

Of the Huronian system he remarks:

"Lying immediately against the Laurentian, and very sharply defined from it, we find, extending from the Montreal river westward for fifty miles, to lake Numakagon, a belt of schistose rocks which we refer unhesitatingly to the Canadian Huronian, and which are beyond question, the direct westward extension of the iron-bearing series of the Upper Peninsula of Michigan," (iii, 6).

The subdivisions of this belt are recognized as follows, (iii, 6):

5. Medium-grained to aphanitic, dark gray mica schists, with coarse intrusive granite. 7,985 feet.

4. Alternations of black mica slate with dioryte and schistose quartzytes, and unfilled gaps. 3,495 feet.

3. Tremolitic magnetite schists, magnetitic and specular quartzytes — forming the Penokee Iron range. 780 feet.

*Geology of Wisconsin, vol. i, p. 352, 1883.

2. Straw-colored to greenish quartz-schist, and argillitic mica schist, often novaculyte. 410 feet.
1. Crystalline tremolitic limestone, at times overlaid by a band of white arenaceous quartzyte, and at times absent, the next formation above them coming into contact with the Laurentian. 130 feet.

As the identification of the Penokee series with the Huronian is still a subject of debate, professor Irving's affirmative reasons possess interest:

(1). There appears to be a direct continuation with the iron-bearing system of the Marquette region of Michigan; (2). The grand subdivisions of the Bad river [Penokee] and Marquette systems are strikingly similar; * (3). The Bad river and Marquette systems both show the same relation to the Laurentian and Keweenawan systems as found in the Huronian of Canada; i. e. are newer than the former and older than the latter; (4). The Marquette system is found in unconformable contact with the Lower Silurian red sandstone of lake Superior, and also in the Menominee region, is also found in unconformable contact with the fossiliferous Primordial sandstones of the Mississippi valley (iii, p. 7).†

The boldest feature of the views promulgated at this time, was the characterization of the "Keweenawan System," a step foreshadowed in 1877, and evidently meditated since 1874. This widely extended Michigan-Wisconsin system is thus described:

"It is a distinctly stratified system, but is in large measure made up of eruptive rocks in the form of great flows. These appear to constitute in Wisconsin, the lower ten thousand to thirty thousand feet of the system, apparently without interstratified detrital beds. Above these, we find the detrital beds increasing in frequency, until they seem to exclude the igneous rocks altogether; the upper portions for some fifteen thousand feet, being apparently composed wholly of sandstone and shale, with a heavy mass of conglomerate at base" (iii, 7).

These rocks in northern Wisconsin, form a true synclinal depression, and the Chequamegon bay lies within it, but crowded over to the northern side. The eruptive rocks of the system are chiefly of the augite-plagioclase kind—hornblende when occasion-

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*The stratigraphy of the Penokee Range is given in *Amer. Jour. Sci.* III, xvii, pp. 394-395 and *Geol.of Wis.*, iii, p 450, table, and in full detail in the same volume, pp. 103-166. On the "Mica Schists and Black slates," see Van Hise, *Amer. Jour. Sci.*, III, xxxi, 453-459, 1886. On the "Iron Ores" of the series, see Van Hise, *Amer. Jour. Sci.*, III, xxxvii 32-48, 1889. On their "Origin" see Irving, *Amer. Jour. Sci.* III, xxxii 255-272, 1886.

†This identification had been announced previously by Irving in *Amer. Jour. Sci.*, III, xvii, 393-398, 1879. Further on the "Divisibility of the Archæan in the Northwest," see Irving, *Amer. Jour. Sci.*, III, xxix, 237-249, 1885.

ally occurring, being always a paramorphic product of the augite. These eruptives, therefore present a marked distinction from the hornblende-bearing eruptives of the Huronian; and belong to the Rosenbuschian categories, diabase, melaphyr and gabbro. The diabases, which are far the most abundant, occur in distinct beds of overflow, each of which (as first pointed out by Pumpelly and Marvine) is amygdaloidal above, and massive, often columnar below, with an intermediate zone, which Pumpelly designated "pseudo-amygdaloidal." The gabbros are coarse grained, and two varieties are distinguished, the most common being light to dark gray and perfectly crystalline, and the other being red and black mottled, or red and gray mottled, with some of the crystals dulled in appearance, or red-stained by iron infiltration (iii, 10).*

1883. In the progress of these studies, professor Irving devoted much attention to the subjects of paramorphic changes and secondary enlargements in the mineral constituents of rocks; and while not by any means the first to bring these facts to light, he was foremost in extending our knowledge of them, and in illustrating their importance in the history of the rocks. He alludes to the fact that most of the older, dark basic, massive rocks have been called diorytes, because hornblende is joined in them with a triclinic feldspar, while augite seldom occupies the same place. But he says:

"Precisely the reverse of this is the case, the diabases, in fact, being the common kinds, while diorites are everywhere rare. Moreover, in many diorites entitled to be so called by their content of hornblende as a chief constituent, this mineral has been proved to be merely a secondary transformation of augite, remnants of which are here and there to be seen in little cores." †

This, he says, is true of all the diorytes which he had studied in this section, and he entertained little doubt that the same would be found true of the diorytes described by Wichmann from the Menominee region. Hence he concludes that no dioryte as an original rock, has been found in Wisconsin.‡

The work on the Wisconsin survey having closed, professor Irving entered upon a great undertaking, under the auspices of the United States Geological Survey. This was the preparation of "a memoir aiming at a general exposition of the nature, structure and

*This series of beds had in 1873 been named "Keweenaw Group," by T. S. Hunt, (*Trans. Amer. Inst. Mining Eng.*, 1. 331-342); and in 1875, "Keweenawian," by Brooks. Later "Keweenian," the more euphonious form of the name, was proposed by Hunt (Harper's *Annual Record*, 1876). See *Geol. Wis.*, iii, 660. Removing superfluous letters, there remains "Kewenian," the best form of all.

†*Geology of Wisconsin*, vol. i, p. 345, 1883.

‡What is true in Wisconsin is very likely to be true also in Michigan.

extent of the series of rocks in which occurs the well-known native copper of lake Superior." The transmission of this memoir bears date October 25, 1881, but the title page is dated 1883.*

This remarkable work is an amplification of views, and strengthening of positions relating to a newly recognized geological system which in the Wisconsin report had been defined as Keweenawan.† It is not intended to give any synopsis of this volume, nor to point out the excellencies of the treatment; but a few of its more important positions will be stated.

The Lower Group of the Upper Copper-bearing series of Logan —the "Animike" of Hunt—is excluded from the system; but the white and red dolomitic sandstones, in the peninsula between Black and Thunder bays, and thence to lake Nipigon, are included. The horizontal sandstones which form the south shore east of Bete-Grise bay on Keweenaw point, and westward from Clinton point, Wisconsin, are also included. The system, then, "consists of the succession of interbedded traps, amygdaloids, felsitic porphyries porphyry-conglomerates and sandstones, and the conformably overlying thick sandstone, as typically developed in the region of Keweenaw point and Portage lake, on the south shore of lake Superior," (pp. 24, 385).

The volcanic theory of the origin of pebbles forming the conglomeritic beds is combatted. This theory had been promulgated by Houghton in 1841, and Foster and Whitney, in 1850 and 1854.‡ The system is demonstrated to be unconformable with the Huronian below and the Silurian above.

The possibility of a sedimentary origin for any of the stratified semi-amygdaloids§ of the Agate Bay group of beds is "absolutely excluded by the completely crystalline interior texture, the highly vesicular character, the presence of unindividualized magma, the microscopic flowage structure, and the graduation of each bed downward into vertically columnar, non-vesicular olivine-diabase,

*U. S. *Geological Survey*, Clarence King, Director. "The Copper-bearing Rocks of Lake Superior," 4to, pp. 464, with maps and cuts, 1883. [Being Monograph V.] A full digest of this memoir is contained in the *Third Annual Report* of the U. S. Geol. Surv. pp. 93-198. *Bulletin* No. 23, *U. S. Geol. Surv.*, 1885, pp. 124, by R. D. Irving and T. C. Chamberlin, is an important supplement to this memoir.

†This system is set forth in an elementary way suitable for the general reader, by T. C. Chamberlin, in the first volume of the *Wisconsin Report*, pp. 96-118, 1883.

‡Wadsworth also states that Foster and Whitney "remain the best and most accurate exponents of the geology of the country." (*Bull. Mus. Comp. Zool.*, vii *Geol. Ser.*, i, pp. 13, 131); and would thus seem to approve this leading position; yet, without noting his divergence from them, he says: "These conglomerates and sandstones show by the rounded and water-worn character of their constituent pebbles and grains, that they are beach deposits," (*id.*, p. 128).

§Noticed by N. H. Winchell, anté, p. 177, and called by Norwood, "metamorphic hales."

(pp. 138, 287)*. The forms of the "Sawteeth mountains" he refuses to attribute to faulting, and says:

"The case is just such as is found in every region of flat-dipping, hard rocks, and especially where softer layers are interbedded, as in this case," (p. 142).

He regards the dikes seen along the Minnesota shore as sources of the flows of the lake basin; and antagonizes Dr. Selwyn's suggestion of activity through a single vent (p. 144). The "Palisade rock," he says, "is shown under the microscope, to be a quartz-porphyry, with no traces of a clastic nature (p. 187). The central mass of the Porcupine mountains is a quartzose porphyry unquestionably eruptive. Their structure has so much in common with that of the laccolitic mountains in southern Utah, that they might be supposed to owe their existence to an eruption of the porphyry of their central portions. * * But these mountains, he concludes, "owe their existence, in all probability, to a fold, the porphyry of the central portions being one of the usual embedded masses laid bare by subsequent denudation" (pp. 150-1).† He takes the position, and repeats it many times, that the so-called Animike slates are "beyond question, the equivalents of the iron-bearing Huronian of the south shore" (p. 157).

Of the "red rocks" so largely associated with the gabbro of Duluth, he says:

"They lie in it very irregularly, and form nothing like distinct belts, so far as I could make out. They may be seen in great patches hundreds of feet square, and surrounded on all sides by the gabbro, and again, as at the quarry near Rice's Point, in irregular series, from two or three inches to several feet in width. Much the most abundant kind of these red rocks is one which presents macroscopically a wholly crystalline texture and a pinkish color mottled with green. Pink feldspar facets, now and then striated, quartz, and a greenish mineral, may all be made out with the naked eye. Under the microscope, the rock is seen to be chiefly composed of reddened orthoclase; greenish hornblende, quartz and magnetite are also present. The quartz occurs both in quite large patches, and again in little strings running through and through the feldspars, in the usual manner of secondary quartz. A number of these small patches of quartz lying near each other will polarize together, showing that they are part of one individual. Moreover, the same is true of the larger quartz areas, and numbers of small

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*On *a priori* grounds, one might expect unindividualized magma to remain in sedimentary rocks when not completely changed.

†See detailed description, pp. 209-225.

particles lying near them, so that all of the quartz is considered to be secondary. This secondary quartz is frequently scattered through the feldspars in such a manner as to present the appearance of graphic granite, and again it is arranged in irregularly radiating lines. Chlorite is often present as an alteration product of both feldspars and hornblende. No base finer than the rest of the rock was observed, so that the name should apparently be syenite" (pp. 270-1).

Another variety of the "red rock" is described as true granitic porphyry. A rarer variety is a felsitic porphyry. These are all regarded as phases of the same rock.

In describing the Animike rocks in the vicinity of Thunder bay, lake Superior, he sums up by saying that they "consist of a great series, probably upwards of ten thousand feet in thickness, of quartzites which are often arenaceous, quartz-slates, argillaceous or clay slates, magnetic quartzites and sandstones, thin limestone beds, and beds of a cherty and jaspery material," (p. 379). He says also:

"Logan moreover, evidently took as Huronian, that part of the Animike group which 'occupies the coast for a distance of ten miles immediately below the mouth of the Kamanistiquia river, on the north side, leaning in a narrow strip, against the gneiss of the older series,'" (p. 379).

The Animike rocks are confidently identified with the rocks of the Penokee Range; but these latter, as has been stated, were with equal confidence identified with those of the iron-bearing series of Marquette. The Animike must therefore be the equivalent of the Marquette rocks. But Irving endeavored to trace some positive resemblances between the Animike and the rocks of Marquette; but without very convincing results, (pp. 385-6).

At this point the able author is seen to be on the brink of a broad fallacious inference. He takes up the consideration of the "Original Huronian," and correctly concludes:

"It appears to me very probable that the original Huronian of lake Huron and the Animike slates of Thunder bay, and thence southwestward to the Mississippi river, are one and the same formation," (p. 390).

This was the opinion first entertained by Logan;* but he subsequently associated those slates with the overlying Keweenawan. Then, as there was a lower, unconformable mass of slate conglomerates, he concluded to call those Huronian. Irving, however, while still holding to the Huronian character of the Animike,

*Report of Progress, Geol. Surv. of Canada. 1844, p. 29.

seems to have disregarded the vertical slate conglomerates, apparently because they graduate conformably into the crystalline schists and gneisses, and might be taken for a portion of that series —an unconformability between two systems supposed Huronian and Laurentian, having been noted at Penokee gap. Thus Irving held as Huronian what Logan held as a part of the Copper-bearing series; and Logan came to hold as Huronian what Irving took as part of the crystalline schist series. But when Logan based his description on what he now held to be Huronian and Irving overlooked, Irving thought them to apply to the iron series of Vermilion lake (as they readily did), and concluded that to be Huronian, though in truth the rocks graduated into the crystalline schists, while what he had rightly identified with Huronian on Thunder bay, was really an overlying and discordant series. But that discordance Irving had not yet discovered at any actual juxtaposition, and he devoted much effort to showing how two different formations of different dip and strike, might, at some former time, have approached each other with a common dip and strike, (pp. 392-4). In this state of the facts professor Irving feels himself in a dilemma when he reads Dr. Bell's descriptions of assumed Huronian rocks more remote from Thunder bay, and misunderstands Dr. Bell at the same time, as speaking of the rocks which *Irving* had correctly called Huronian. Nevertheless, Irving is able to convince himself that all the areas by anybody called Huronian, agree in such particulars as to justify him in sweeping them all into that category, (p. 395). Irving suspects indeed, that two groups of schists have been confounded by the Canadian geologists—"the iron-bearing schists of the Huronian and the schistose greenish phase of the older gneiss"—but he does not suspect that he has himself identified and confounded two other systems which, unlike these groups, stand in discordant mineralogical and structural relations to each other.

1885. The overlap of professor Irving's Keweenawan studies on systems of older date, was the prelude to a formal investigation of the Huronian system as a specialty. This was undertaken also, under the auspices of the Government survey, and was in progress at the date of his lamented death. But some preliminary papers appeared, from which we may learn the fundamental positions which he was preparing to defend.* In the first memoir, the following areas of older rocks are grouped together under the designation Huronian:

*A first paper entitled "Preliminary Papers on an Investigation of the Archæan Formations of the Northwestern States," was published in the *Fifth Annual Report* of the U. S. Geol. Surv., 1885, pp. 175-242.

The Original Huronian.
The Marquette-Menominee Iron-bearing schists.
The Wisconsin Valley slates.
The Penokee-Gogebic Iron-bearing schists.
The St. Louis, [Minn.] slates.
The Chippewa Valley quartzites.
The Black River Iron-bearing schists.
The Baraboo quartzites.
The Sioux quartzites.
The Animike series.
Folded schists of Canada.

In the progress of a condensed examination of these eleven areas, professor Irving states more explicitly, what he intimated in his previous memoir, that the so-called "crowning overflow," resting on the Animike cliffs of Thunder bay and the regions to the southwest, is not to be regarded as one final overflow, but a succession of overflows, interbedded in a succession of slaty deposits.* He opposes sharply the position of Foster and Whitney, and later, of Wadsworth, that the iron deposits and associated jaspers are of eruptive origin (p. 192). The folded schists north and east of lake Superior, described by the Canadian geologists, since 1863, as Huronian, are admitted, at least some of them, in that system, but he says:

"We are immediately confronted with a structural problem of a good deal of difficulty, *i. e.*, the relation of these folded schists to the unfolded Animike series. Generally as the Animike series is traced toward its northern border, it is found to lie against a belt of granite and gneiss. This is so along the shore of Thunder bay, and thence westward to Gunflint lake, and it is true again at the Mesabi Range and Pokegama falls district, in Minnesota. North of this belt of granite, comes the belt of folded schists. The appearance thus presented is at first sight, one of general unconformity between the flat-lying Animike and an older series including gneiss and older folded schists."

This state of facts was in direct conflict with his theory that the Animike and the folded (vertical) schists are one. The reconciliation of the facts and the theory occupied his earnest attention. A hypothesis was proposed for this purpose.† He supposes "that the Animike rocks were once continuous with the folded schists to the north of them, and that they are now separated merely because

*P. 203. See also, *Fifth Annual Report*, p. 382. The "crowning overflow" is now discredited by the present Director of the Canadian Survey—*Science*, ii, p. 675, 1884.

†*Third Annual Report, Wisconsin Geol. Surv.*, p. 171; *Monographs U. S. Geol. Surv.*, vol. v. pp. 399. 417; *Fifth Annual Report*, p. 206.

of the erosion of the crowns of the folds between them, the close folding of the folded schists being supposed, on this view, to have been produced concomitantly with the broad simple bend which forms the trough of lake Superior. On this supposition, the unfolded schists of the north shore are compared with the unfolded Penokee of the south shore; and the folded schists of the national boundary, with the folded schists of the Marquette and Menominee regions. All are supposed to represent a great sheet of Huronian deposits once continuously spread upon a floor of far older gneisses and schists, which have since been brought to view by folding and denudation."*

Some little support for this not impossible hypothesis, was gathered from the fact, that in one region, where the horizontal and vertical schists were separated by only a few miles, the horizontal schists acquired considerable dip. In some localities, as shown by N. H. Winchell, they became irregular in dip, and manifestly disturbed. But professor Irving was never able to proceed further.†

In the sequel of this memoir, the author presents other results of studies upon his general problem, and among them are interesting facts respecting enlargements of quartz fragments (pp. 229-230); and these lead him to an explanation of so-called "crystalline sandstones". (p. 219)‡ A final conclusion from these studies is "that all of the quartzites marked provisionally as Huronian on the accompanying map, including the type Huronian of lake Huron, are merely sandstones which have received various degrees of induration by the interstitial deposition of a silicious cement which has generally taken the form of enlargements of the original quartz fragments, less commonly, of minute, independently oriented areas, and still less commonly, of an amorphous or chalcedonic silica, two or even three forms of the cementing silica occurring at times together in the same rock" (p. 236).

**Fifth Annual Report, U. S. Geol. Surv.*, pp. 206-207.

†The writer will here state that the Minnesota Survey has shown that the disturbances referred to (east of Ogishkemuncie lake) are very local, and the horizontal schists north of Gunflint lake are not separated from the vertical by a gneissic interposition, but rest in very discordant contact upon them. No more speculation is necessary.

Professor Irving read a paper before the *National Academy*, Apr. 22, 1887, which was published in *Amer. Jour. Sci.*, III, xxxiv, 204-216; 249-263; 363-374, entitled, "Have We a Huronian Group?" This was chiefly an occasion for restating the views presented in the paper here noticed, and for a final effort to elucidate his hypothesis for the synchronization of the Animike and the older schists now known as Kewatin. This paper has been noticed by me in *Bull. Geol. Soc. Amer.*, i. p. 387.

‡The subject has been more fully treated in *Bulletin U. S. Geol. Surv.*, No. 8, 1884, by R. D. Irving and C. R. VanHise.

Such enlargements in "Hornblendes and Augites" have subsequently been described by professor C. R. VanHise, *Amer. Jour. Sci.* III. xxxiii, 385-388, 1887.

The subject of enlargements of feldspar fragments is similarly discussed and the facts established.

A final conclusion from all the facts is that the most of the rocks generally styled Huronian do not properly fall under the head of metamorphic rocks.

These inferences are carried further in the important Bulletin cited above.

1888. The last important memoir from Professor Irving's pen is a compilation of fundamental principles to be employed in the classification of unfossiliferous rocks.*

Of this the author says: "Beyond many of the facts cited in illustration, and the mode of presentation, the paper does not contain very much that is new or original." It nevertheless presents a convenient synopsis of principles, and shows a mature mastery of the subject. For the present purpose a few quotations of new or maturing views on certain points, will suffice. Speaking of the green schists which with more or less of mica schists and other later rocks has been marked as Huronian for the entire region north of lake Superior by the Canadian survey, he says they are not separated from the Laurentian by any unconformity. Therefore, "The name Huronian belongs to an entirely different group."†

In attempting to illustrate the structural relation of the Animike series to the underlying schists, he presents (p. 421) a diagram section across Gunflint lake, which sets forth the observed facts with sufficient accuracy. But his interpretation of the fact seems to be erroneous. He says the Animike abuts "against an older formation of granite and schists," and he says too, "the iron-bearing horizon at the base of this succession [the Animike] is lithologically identical with that of the Penokee series of northern Wisconsin and Michigan." So far he is perhaps, right—but, with the understanding that the "granite" [gneiss] is quite removed from the *contact* with the Animike, and that the "schists" *at* the contact are not the usual crystalline schists which succeed the gneiss and granite, but hold a position superior to them, in the same vicinity. Professor Irving's misconception consisted in regarding those vertical "schists" as part of the series of crystalline schists, and in conceiving them as different from the vertical schists which inclose the iron ores at Vermilion lake. Identifying these vertically-standing ore beds with those in the flat-lying Animike, he makes

*"On the Classification of the Early Cambrian and Pre-Cambrian Formations. A brief Discussion of Principles, illustrated by examples drawn mainly from the Lake Superior Region." *Seventh Annual Report* U. S. Geol. Surv., 1888, pp. 363-454.

†Yet this is precisely the group which in the Vermilion region of Minnesota, professor Irving calls Huronian

an unsuccessful attempt to represent them as "flat-lying," like the Animike ores at Gunflint lake* (p. 421).

Professor Irving insisted on a "structural unconformity between the Huronian and Laurentian." He makes numerous references to Sir William Logan's utterances on the subject, and though they are strikingly self-contradictory, Irving asserts, they "show certainly his full belief in such unconformity" (p. 430). This confusion on Logan's part, and misapprehension on Irving's, arise from their common error in applying the name Huronian to two different systems, and Irving's supposition that the Penokee Huronian—rightly identified with the original Huronian—is the same as Logan's "Lake Superior Huronian."

In discussing the taxonomic exhibit which he gives of the older rocks (pp. 440-441) he says:

"At the base of the succession is a series composed of gneiss and granitic rocks, with also a large development of schists. The granite is certainly in the main eruptive. The schists are very largely compressed eruptives, but also in part of sedimentary origin" (p. 442). This view may be compared with those given, anté, p. 197.

But of the mica schists or mica slates described as holding a position near the top of the Marquette iron series, he says:

"Our own microscopical studies of them have demonstrated their derivation by mere metasomatic changes, from rocks wholly of detrital origin, the fragmental character frequently being well preserved, even to the naked eye, while large portions of the same horizon show little change from the original fragmental conditions." (p. 386.)†

As the outcome of the entire discussion, professor Irving presents the following taxonomic suggestion (p. 454):

Systems.	*Groups.*	*Systems.*
Paleozoic.	Carboniferous, Devonian, Silurian, Cambrian.	Paleozoic.
Agnotozoic or Eparchæan.	Keweenawan, Huronian, (Other groups?)	
Archæan.	Laurentian (including upper Laurentian.)	Archæan.

* His diagram attempting this is in *Amer. Jour. Sci.*, III. xxxiv, p. 259.

† Such micaceous schists are what the writer, in the Fifteenth and Sixteenth Minnesota Reports, has styled "nascent mica schists."

ANDREW C. LAWSON.

1886. In his description and estimate of the rocks in the vicinity of the Lake of the Woods,* Dr. Lawson assumed positions of such originality and boldness as to entitle his contributions to an important place in this sketch of opinions concerning the older rocks of America.

The schists in the vicinity of the Lake of the Woods had been noticed by Bigsby and the other early explorers. By Bell, they had been designated Huronian, from their resemblance, undoubtedly, to the schists misnamed Huronian, on the north and east of lake Superior.† Dr. G. M. Dawson first remarked the apparent volcanic origin of a large part of the "Huronian" ‡rocks.

Dr. Lawson is not satisfied to embrace all the older schists in the Huronian.§ He says:

"The schistose belt of the Lake of the Woods appears to me to differ from the typical Huronian of Sir William Logan both lithologically and in other respects. The typical Huronian of Logan is, from his description of it, essentially a quartzite series, in which the quartzites are true indurated sandstones. The schistose belt of the Lake of the Woods is not so characterized. Quartzites form an extremely small proportion of the rocks of the Lake of the Woods, and then they are only local developments in formations of mica schist and felsite schist. Bedded limestones are characteristic of Logan's typical series. On the Lake of the Woods, there are, so far as I have been able to determine, no bedded limestones, the nearest approach to them being small segregated bands of dolomite of the character of veinstones. These two differences alone are sufficient to throw doubt on the equivalence of the two series, if lithological character is to be regarded as an aid to geological classification. There are, however, other differences. The basal conglomerate of Logan's Huronian, on Lake Temiscamang,

*Report on the geology of the Lake of the Woods region, with special reference to the Keewatin (Huronian?) belt of the Archean Rocks. By Andrew C. Lawson, M. A. *Geological and Natural History survey of Canada.* Annual report (new series), Vol. i, 1885, Montreal, 1886.

†R. Bell, *Ann. Rep. Canada*, 1872-3, pp. 91-105; 1873-4, pp. 88-89. Also, and more in detail, 1880-2, pp. 12-15C.

‡G. M. Dawson, Geology and resources of the region in the vicinity of the forty-ninth parallel, 1875.

§The same dissent was expressed by the writer in a paper on "The Huronian System," presented to the *Amer. Assoc.*, New York, 1887; in one entitled, Systematic Results of a Field Study of the Archæan Rocks of the Northwest, *Proc. Amer. Assoc.*, Cleveland, 1888, p. 205-6; a paper on The Geological Position of the Ogishke Conglomerate, *Proc. Amer. Assoc.*, Toronto, 1889, pp. 234-5 and Two Systems confounded in the Huronian, *Amer. Geol.* iii, 212-14, March, 1889. See similar views embodied in a paper by N. H. and H. V. Winchell, *Proc. Amer. Assoc.* Toronto, 1889, pp. 235-242.

is described as holding pebbles and boulders, sometimes a foot in diameter, of the subjacent gneiss, from which they appear to be derived. The boulders display red orthoclase feldspar, translucent colorless quartz, green hornblende and brownish black mica arranged in parallel layers, which have a direction according to the attitude in which the boulders were accidentally inclosed. The rocks on the Lake of the Woods, which are in the following pages referred to as agglomerate schists, are not basal conglomerates. They are not at the base of the series included in the schistose belt, nor are they apparently composed of water-worn fragments, derived from the rocks upon which they rest.

"No fragments that can be referred to the underlying granitoid gneisses are found included in the agglomerate schists of the Lake of the Woods. All the facts connected with them point to a volcanic origin for these agglomerates, and the fragments are very frequently sharply angular, often with re-entering angles, although for the most part, they are elongated and lenticular in shape, as a result of pressure, and the paste in which they are imbedded does not differ from them materially, as a rule. In rare instances, they pass into a pebble or boulder-conglomerate, in which the pebbles are usually of a reddish felsitic material, and indicate the coëxistence of aqueous with volcanic deposition."

"The 'green slate rock' conglomerates at the mouth of the Doré river, lake Superior, described by Sir W. Logan, supposed by him to be equivalent to the rocks of his main Huronian area, appear to resemble the agglomerate schists of the Lake of the Woods. This Doré river area of 'green slate rocks,' is however geographically distinct, and appears to differ from the series in the typical Huronian region. The rocks are described as standing in a nearly vertical attitude, while those of the latter are comparatively flat. Neither are they associated with beds of quartzites or limestones to a material extent. Those differences, with the geographical separation, may, I believe, warrant us in considering the possibility of Logan having placed under one designation, two distinct series."

Other and good reasons are given for the opinions here set forth, but we must forbear to cite further.

"While thus the schists of the Lake of the Woods are older than the epoch of folding, and older than the granites which are intruded through them, Logan's typical Huronian has come into existence later than the time of folding of the gneiss, and possibly also, later than the main period of granitic irruption."

He refers to Irving's conclusions as supporting his own view. Citing Irving's full identification of the Animike series of Thunder

bay with the typical Huronian, and his view of the apparent equivalence of each with the Marquette, Menominee and Penokee-Gogebic series, he asks:

"If then, the Animike and Huronian are identical, as Logan himself believed, as regards a portion, at least, of the Animike, what are the relations of the folded schists of the Lake of the Woods to that flat-lying series? Professor Irving has expressed the opinion 'that both the flat-lying Animike slates and the more northern, folded, iron-bearing schists are Huronian,' and gives a diagram to show the hypothetical identity of the folded and unfolded series on either side of the Mesabi range of granite and gneiss" (See anté, p. 203).

"The folded schists to the northwest, however, so far as the Lake of the Woods series teaches, are as different from the Animike as they are from the typical Huronian, and were probably folded with the gneisses, before the Animike rocks existed as such. The Animike series rests, apparently, on granite, along part of its western confines. The granite of the region appears, as is known to have been the case on the Lake of the Woods, and has been more recently determined to be true also for Rainy lake, to be of later origin than the folded schists*. Hence, in the superposition of the Animike rocks upon the granite, we have, again, a sharp distinction in geological time, between the Animike (Huronian?) and the folded schists to the west, as represented by the Lake of the Woods series."

Dr. Lawson thinks, in this view of the facts, "it is expedient that this series of rocks should receive a convenient name which shall be non-committal as to geological relations, and which may be used provisionally, till such time as those relations are established beyond question. The most appropriate name for the series that suggests itself to me is *Keewatin* [*Ke-way-tin*], the Indian name for Northwest, or the Northwest wind, which has been applied to the district within which the rocks occur."†

*This view of the relative age of the granites and the schists has been more particularly argued by Dr. Lawson, in *Amer. Jour. Sci*, III, xxxiii, 473-480. Although the author speaks with confidence, the reader will not understand that the doctrine is established in the sense here conveyed.

†*Keewatin* as a Chippewayan term, has no authorized orthography. The sounds are represented in different European languages, according to the powers of the letters of those languages. It is doubtful whether the usage of the English language has a paramount right to impose a fixed form for universal acceptance on any Indian vocable, especially, when it is a term proposed for introduction into the universal language of geology. This diversity in the powers of letters in different languages, led Americanists long since, to the adoption of certain rules for the spelling of Indian names. The alphabet of Dr. George Gibbs, the recognized pioneer in American linguistics, was adopted by the Smithsonian Institution, and published with its sanction, in No. 160 of Smithsonian Miscellaneous Collections, 1866. The rules thus pro-

Coming to a geological description of the region, the author dwells upon the existence of great pre-glacial denudation; but in a later memoir, this subject is treated more at length.

To the gneissic and granitic rocks he ascribes an origin from molten material. He states that the non-orthoclastic constituents of the gneiss possess "a distinct flowed structure." The gneisses, he says, too, show a "passage into granites devoid of foliation" (p. 29). Of one of the granites he says:

"This rock, characteristically granitic in its nature, may be traced eastward over a comparatively bare country, and be seen to assume gradually, by transitions scarcely perceptible, a gneissic arrangement of the crystals, till at last, on the shores of Long lake, it presents a quite distinctly gneissic foliation" (p. 30).

A group of rocks of great importance but very obscure nature, is described as "agglomerates, tuffs and boulder conglomerates." The character which they present he considers due to "an extremely rapid process of deposition of intimately associated and often alternating, volcanic ejectamenta, (both flows and tuffs) and aqueous sedimentation, the material for which was derived partly from the volcanic products, and partly from the more silicious or acidic rocks which seem to have constituted the original floor of the trough" (p. 49).*

Further of the constitution of the agglomerates, he says:

"The included fragments of the agglomerates are nearly always more or less flattened or lens-shape, the greatest planes in the fragments being parallel with the planes of schistosity, which are in the great majority of cases observably identical with those of the bedding" (pp. 49-50).

The forms of the fragments are attributed to pressure. The agglomerates are said to pass, sometimes, into mica schists; and he says it is "not uncommon to find in these mica schists, a small proportion of feldspar, which gives them the character of finely laminated gneisses, in places."

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mulgated have been followed in the various publications of vocabularies made by the U. S. Department of Ethnology. (See, for instance, Contributions to North American Ethnology, vol. i. p. 249, 1877, and iii, p. 443, 1877). Under these rules, the vocable *Ke-way-tin* should be written *Ki-wé-tin*; as the vocable *Ke-we-naw* would be written *Ki-wi-na*. But should it be considered too late to adopt the Smithsonian orthography of these words, there certainly is no English reason for inserting duplicated "*e*", as in *Keewatin* and *Keweenaw* (why not *Keeweenaw?*). The least concession to the demands of simplicity and good orthographic reason, should prompt a user of the English language to write *Kewatin* and *Kewenaw*. For similar reasons, we should write *Animike*, not *Animikie* or *Animiké*; *Ke-ke-qua-bic*, not *Ka-ka-quà-bic*. Also, *Couchiching*, not *Coutchiching*.

*A similar view of the nature of the "diabasic schists" of Minnesota has been set forth by H. V. Winchell, in the *American Geologist*, iii, pp. 18-22. Jan. 1889.

Thus, since the gneiss graduates into granite, he discovers a mineralogical graduation between mica schist and granite.*

Particular attention is devoted to the relations of the gneisses with the associated schists. "The gneiss", he says, "in some places, holds large and small angular fragments of hornblende schist . . The planes of *lamination* of the schist and *foliation* of the gneiss are parallel, though there are *unmistakable* evidences that the contact is an igneous one, and that when there is a mixed alternation of gneiss and schist, the former has been *injected* within the latter [italics are the compiler's]. This mixture of gneiss and schist, with occasional short broken bands and fragments of schist included within the gneiss, occur at intervals along the shore of Darlington bay" (p. 64).

In another place, he speaks of "dykes and gneiss" cutting the schists, and presenting the appearance of "evenly intercalated beds" (p. 72). As we approach the great gneissic area, these intercalations become more frequent. At the junction between the gneiss and schists, there is "no sharply defined line of contact, but a transitional series of layers of alternate gneiss and schist" (p. 72).

He gives figures of such alternations, and says:

"The two rocks [are] apparently interbedded as a transitional alternation, but the gneiss [is] in reality intruded." In one place he enumerates sixteen alternations of gneiss and hornblende schist, "some of the gneissic beds being as thin as four inches, six inches, eight inches and one foot, with intervening schistic beds as low as eight, twelve and fifteen inches, all regular and bed-like in their characters;" "but their true nature," he says, "as injected sheets or dykes, is sufficiently revealed." This opinion seems to be rested on the facts that occasionally a bed of gneiss sends "irregular tongues" into the schists, or includes "fragments of the schist walls."†

The plutonic view is defended by the author with unmistakable ability, (p. 83, etc); but we have not the space for adequate citations. The Kewatin is held, with reserve, to be structurally conformable with the Laurentian; but at the same time, it is presumable that a real historic break separates them.

*Nevertheless, so far as the writer can ascertain, he regards the Kewatin as embracing all the rocks down to the gneiss, where, for the reasons given, he discovers evidences of a very different sort of geologic agency.

†Similar relations of gneiss and contiguous schists are described in the *Fifteenth* and *Sixteenth Annual Reports* of Minnesota; but a different interpretation is put upon the gneissic beds. See also the writer's memoir in *Bull. Geog. Soc. Amer.*, pp. 357-394. Apr., 1890.

As to the general structure of the region, he says:

"The granitic intrusions of the area of the Lake of the Woods may be grouped under ten main centres of occurrence or distribution, with a number of bosses of minor importance, which appear to be independent of these."

These areas are regarded as so many outbursts through the overlying Kewatin and are therefore of later age. The granitic masses have a definite relation to the stratigraphical structure, and seem to lie in the lines of folding, and to have been affected by the same cause as produced the folding (pp. 100, 101).

Of the Kewatin series he enumerates and describes the following members:

"Granitoid rocks at either extreme.

"Hornblende schists with associated altered traps, the whole more or less chloritic.

"Agglomerate schists, varying in character from greenstones to micaceous or gneissic schists.

"Quartzose mica schist, sometimes gneissic, but lamination very even.

"Hydromicaceous and chloritic schists, and arenaceous slates.

"Granite (irruptive)."

1887. In continuation of the results of his studies in the Canadian Northwest, Dr. Lawson gave a preliminary account of the geology of the Rainy lake region.* This region geologically is a continuation of that of the Lake of the Woods. He here brings out more expressly his belief that the granitic and gneissic rocks are younger in respect to the conditions in which we know them, than are the crystalline and semi-crystalline schists. He says truly:

"We do not yet know their original condition prior to the fusion from which they solidified into granites, syenites and gneisses. They may have been sedimentary; they may have been the original crust of the earth. But whatever may have been that original condition, the evidence is clear on this point, viz: that the fusion and solidification whereby they were brought into their present condition as firm crystalline rocks, took place at a period subsequent to the existence, in a hard, brittle condition, of the stratiform, and often very distinctly clastic, rocks which occupy the higher place in the column. Therefore, as rocks, the members of this fundamental system are of younger age than those of the nearest overlying formations."

But he draws the line of distinction between igneous and sedi-

*Amer. Jour. Sci., III, xxxiii, 473-480, June. 1887.

mentary rocks at the crystalline schists. He includes here certain fine-grained, bedded rocks for which he proposes the term "*granulite gneiss*."* The schists generally known as crystalline schists, occupying a position between the gneisses and the semi-crystalline schists, are here separated from the latter, and receive the name, "Coutchiching series."†

He says of them:

"They are very sharply and distinctly marked off from the lower granites and gneisses of the Laurentian. The geological contact between the Coutchiching series and the Laurentian is one of neither conformity nor unconformity. The break is of an entirely different order, and the contact is eminently that of an igneous injection or intrusion of the lower through the upper rocks" (p. 4/7),

The overlying [Kewatin] schists are "of entirely different character." The rocks are for the greater part "of volcanic origin' Though structurally conformable with the Couchiching series, the appearance of parallelism may be the result of folding and pressure. The diverse character of the rocks of the two series is proof of a profound alteration in the conditions of rock formation, which implies a geological break.

Regarding the systems in order of superposition, he arranges them thus:

Kewenawan (Nipigon).
Huronian (Animike).
Kewatin.
Couchiching.
Laurentian.

But regarding them in the order of age, they would stand thus:

Kewenawan (Nipigon).
Huronian (Animike).
  Diabase dykes and gabbro,
  Granite, post-Laurentian.
Laurentian.
Kewatin.
Couchiching

1888. Dr. Lawson's final report on the geology of Rainy lake region appeared in 1888.‡ This thoroughly scientific memoir, in the discussion of doctrines, is devoted rather to the strengthening

*This convenient and appropriate term has been used many years by the present writer. This, as also "granulite schist," are given in his "Geological Studies," pp 51 74, 76, etc, 1886.

†Better *Couchiching*, for reasons stated above.

‡*Geological and Natural History Survey of Canada.* Annual Report (New Series), vol III, Part I, pp. 182, with a map.

of positions previously assumed than to the elimination of new views, and thus, in spite of its value, does not seem to demand more than the citation of a few passages. Among the facts however, which possess greatest interest, are some occurrences of a conglomerate which, as nearly as may be judged, is an extension of the Ogishke conglomerate of Minnesota.

"On the shores of Rat-Root bay, the basal beds of the Keewatin are pebble-conglomerates, of which the paste is a green schist, and the pebbles mostly water-worn, rounded or oval pieces of vitreous or saccharoidal quartz. Some of the pebbles are feldspathic, and when so, are occasionally foliated. On the south shore of the bay, boulders of granite are observed to form part of the conglomerate, one boulder being at least eighteen inches in diameter, and of a roughly rounded shape" (pp. 38, 82, 105).

Again on Grassy lake, the basal beds of the Kewatin "are fissile, soft, green-chloritic and hornblendic schists, the detrital origin of which is established by the fact that on the north side of the lake, they constitute the paste of a pebble-and-boulder-conglomerate" (pp. 55, 82). This conglomerate is much more voluminous on the north side of Shoal lake.

Among the soft fissile, glossy gray schists of the Kewatin series at the west end of Schist lake, there are several beds of conglomerate, the pebbles of which are mostly quartz rock, and the matrix a soft, more or less calcareous, decomposed schist, stained yellowish with oxide of iron.

He notes the parallelism of the two series and says again, this affords but little evidence of original conformity; and relies upon the abrupt lithological contrast for evidence of a historical break. The conglomerate he regards as a *basal** conglomerate "in which the pebbles have very probably been derived from the underlying formation" (pp. 56, 105).

He notes, what has also been observed in Minnesota, that the series of crystalline schists is quite inconstant in its occurrence. Sometimes the Kewatin rests on the gneiss, and then the basal member is likely to be hornblende schist. But this schist is apt to be wanting when the Kewatin rests on mica schist (p. 38).

Of the hornblende schists he says:

"There is much presumptive evidence in favor of the view that they are partly altered, massive rocks, and partly altered, volcanic ash-beds (pyroclastic), but little or none, that they are the alteration products of clays or other forms of detrital matter."

*This position of the Ogishke Conglomerate of Minnesota has seemed to the writer clearly pointed out by the facts observed. See *Sixteenth Ann. Rep.* Minn. pp. 344-350; 359-360.

The changes undergone have been so profound that the original character has been destroyed, and a new rock of different constituent minerals has crystallized *in situ*. Pressure and crushing may have been potent in the destruction of the original structure; but in the later history, chemical or metamorphic forces have been chiefly active, and have obliterated all the traces of crushing (p. 73).

Of the soft, fissile, green schists he says:

"These are schists closely resembling the paste of some of the conglomerates. They are usually distinctly bedded. Their clastic origin can scarcely be doubted, though, as in the paste of some of the conglomerates, their association with bedded traps and their mineralogical analogy with the altered phases of those traps, renders it extremely probable they were never ordinary clays, but were originally fine-grained, volcanic ash-beds, the constituent minerals of which have suffered alteration and decomposition along the same lines as those observable in the traps" (p. 82).

He finds few serpentines. Their relations to the rocks adjoining them are ill-defined. They appear to be the alteration products of igneous masses which have the same geological age as the traps and other volcanic rocks of the Kewatin series; and although their common boss-like character suggests that they are intrusive through the Kewatin rocks, such intrusion has probably taken place coëval with the bedded formations, volcanic and sedimentary, of the Kewatin (p. 97).

In reference to the relations of the Couchiching series to the Kewatin and Laurentian, he remarks:

"Without being able to conclusively prove it, there appears to be much presumptive evidence in the facts cited, to show that the present eminently crystalline state of the Coutchiching series is the result of the metamorphism of strata which were originally in large part, ordinary quartzose sediment, although part may possibly have been acid volcanic rocks, such as quartz-porphyries or felsites. In many parts of the series garnets abound, and if the rocks were carefully examined, other metamorphic minerals would doubtless be found. That percolating silicious solutions were active agencies in effecting the metamorphism of these strata, is proved by the fact that in many places, particularly on the north side of Saginaw bay and east of Brulé narrows, the partings between the beds have served as fissures for the deposition of vein-quartz. This vein-quartz is very abundant in lenses or lens-like sheets, and is clearly a secondary product in the rock. The same watery solutions which desposited the quartz in these lenses, in the more open portions of the formation, must have saturated the

rock throughout, and given rise, probably, to much of the quartz and feldspar in it. Only in one instance has hornblende been observed throughout the whole series. There are no intercalations of basic volcanic rocks, and none that can now be distinctly recognized as acid volcanic rocks. There are no limestones or dolomites in the series, nor have any conglomerates been observed." (p. 105.)

The subject of inclusions in the Laurentian gneiss is very particularly treated. These gneisses, both of the granite and the syenite type, frequently consitute a matrix in which angular fragments of schists are inclosed. These are most abundant in the vicinity of the lines of junction with the overlying schists. The included fragments may belong either to the Couchiching or Kewatin series. Along the zone of contact, apophyses or dykes from the gneiss penetrate the contiguous sheets. These facts are thought to prove that the inclusions are simply detached portions of the overlying formations "which in a firm and brittle condition, have become immersed in the underlying viscid magma, which subsequently crystallized out as the Laurentian gneiss and granite. It seems probable, too, that such shattering and detachment of fragments took place at the last stages of crumpling of the crust in this region. . . After the solidification of the Laurentian gneisses, there was no farther very violent deformation of the crust, for the Laurentian rocks appear to have resulted from the fusion not simply of the floor upon which the Coutchiching and Kewatin rock first rested—what ever such floor may have been*—but also with it of portions of those series" (pp. 130, 131).†

1890. Early this year, Dr. Lawson published a thoughtful and important memoir on the internal relations and taxonomy of the Archæan of Canada.‡ He discusses, first, the separability of the Archæan into two divisions, which, with subdivisions, would present the following scheme:

*The recognition of the necessity of a "floor" on which the marine sediments could have rested, is a tacit admission of the existence of a geological formation older than that formed from the sediments. To say that we know nothing of that solid floor except as an inference, is the same as we must say about the former fused or plastic condition of the granites and gneisses. The indications of such plasticity afford no stronger basis for the inference than the indisputable necessity of a solid non-igneous sea-bottom to support the waters of a sediment-laden ocean. We have, in reason, in both cases, satisfactory ground for a conclusion, and in both cases, proof from observation is precluded. In fact, the conclusion that molten masses of granite emerged through or into beds of strata already existing, possesses the same kind of support as the conclusion that a solid foundation earlier existed for the penetrated strata to accumulate upon. It is, in short, demonstrable that the schists have no claim to be reckoned first in the order of time.

†Phenomena of the class here described have also been fully detailed, with many illustrations, from the contigous territory of northern Minnesota. See *Fifteenth* and *Sixteenth Annual Reports, Geol. Surv. Minn.*, 1886, 1887.

‡*Bulletin of the Geological Society of America*. pp. 175-194, March 20.

ARCHÆAN.
Ontarian. [Now first proposed.]
Kewenian.* [Nipigon.]
Huronian. [Animike.]
Kewatin.* [Often confounded with Huronian]
Couchiching.* [Vermilion of N. H. Winchell.]
Laurentian.

In presenting a petrographical description of the members of the Ontarian division he says of the hornblende schists:

"The field evidence points to their derivation from basic volcanic rocks," and cites examples from Norway and Scotland tending to prove "the derivation of the bulk of the hornblende schists from normal volcanic massive rocks, which were originally bedded with other stratified rocks, either as flows or as injected sills. Other hornblende schists are probably derived from an analogous alteration of tuffs of basic volcanic rocks" (p. 179).

As to the extent of the influence of metamorphism in the Ontarian system, Dr. Lawson offers reflections which narrow the gap between him and the metamorphic school. He says:

"In deference to these [plutonists] and other anti-metamorphic schools of thought, in which for the most part, theory seems to crowd out fact, it becomes necessary, with the accumulation of evidence of recent years, to point out the great additional strength acquired by the theory of metamorphism as applied to the Archæan by the recognition of the volcanic origin of much of the material upon which metamorphic agencies have operated, and by the limitation of its application to the upper division [Ontarian] of the Archæan; the rocks of the lower division, or Laurentian, being susceptible of an entirely different explanation. The lack of discrimination between the essentially different characters of the upper and lower Archæan, and the lumping of the whole complex together as having necessarily the same origin and development has been the great mistake alike of the metamorphic and the extreme plutonic schools. Just as the metamorphic theory, properly limited, affords the explanation of the development of the rocks of

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*Kewenian is not named in this connection, but in previous documents it is put in the position here indicated.

Although this slightly simplified orthography of three of these divisions is here used by the writer, the terms are considered the same as those employed by Dr. Lawson.

In writing of the Couchiching series, for which the name "Vermilion series" was employed by N. H. Winchell about the same time as proposed by Dr. Lawson, he takes occasion to express regrets that the present writer had used "Vermilion series" and "Vermilion system" "in a much more comprehensive, but still undefined sense." It is proper to say that those expressions were not intended as taxonomic in value, but simply as geographical, referring to the whole assemblage of rocks about Vermilion lake.

the upper Archæan from normal formations, so by a similar limitation of the plutonic theory, and the introduction of some modifying considerations, we will find in the latter, a rational and consistent explanation of the origin of the rocks of the Laurentian" (p. 181).

In another memoir, Dr. Lawson has recorded* important observations on the pre-Palæozoic surface of the Archæan terranes of Canada. The surface known as *roches moutonnées*, generally attributed to the action exerted during the last glaciation, is seen to have existed when the Palæozoic sediments were laid down—formations of whatever age adapting their under surfaces to the bossy surface of the Archæan.

Another announcement possesses similar interest. Vestiges of Palæozoic strata are now known in so many districts resting in the protected depressions of the Archæan, that it appears probable that a large part of the Archæan surface was once covered by a blanket of fossiliferous rocks. In this view, the region which we call the Archæan nucleus of the continent was not visibly such until after a vast amount of denudation; though of course, it really existed as a grand swell in the fundamental structure of North America. A further inference from such a fact is the certainty that the material of the Palæozoic sediments was derived from some source now lost to view.

It becomes necessary to bring to a close our citations from the views of American workers on the nature and history of the older rocks. Though the undertaking has produced more voluminous results than were anticipated, there still remains a large body of valuable opinions, to which justice demands, probably, that some reference be made—opinions both of those who have been quoted, and opinions of others who, thus far, have been but incidentally mentioned. Regretting the necessity for these omissions, the compiler hopes, nevertheless, that what has been presented, may prove useful to many students in this difficult field of inquiry.

ERRATA.

Page 77—For "Bucoides" read Fucoides.
Page 83—For "It is intended" read It is not intended.
Page 108—After "Georgia trilobites" insert to.
Page 113—Dele "[4]" and five lines below substitute [4] for [5].
Page 126—Last line for x read plus.
Page 207—For "resents the following" read presents the following.

* *Bull. Geol. Soc. Amer.* 163-174, March 12, 1890.

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PUBLICATIONS OF THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

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THE FIRST ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1872. 112 pp., 8vo.; with a colored map of the state. By *N. H. Winchell*. Published in the Regents' Report for 1872; Second edition identical.

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4. A CATALOGUE OF THE PLANTS OF MINNESOTA. Prepared in 1865, by *I. A. Lapham*, contributed to the Geological and Natural History Survey of Minnesota, and published by the State Horticultural Society in 1875.
5. CIRCULAR NO. 2. Relating to botany, and giving general directions for collecting information on the flora of the state. 1876.

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10. CIRCULAR NO. 6. To owners of mills and unimproved water-powers. Relating to the hydrology and water powers of Minnesota. 1880.

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No. 4. A synopsis of the Aphididæ of Minnesota By *O. W. Oestlund.*

No. 5. Natural Gas in Minnesota. By *N. H. Winchell.*

No. 6. The Iron Ores of Minnesota. *N. H. Winchell* and *H. V. Winchell.* In press.

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*Died Oct. 4, 1890.

ADDRESS.

THE UNIVERSITY OF MINNESOTA.

MINNEAPOLIS, August 1, 1891.

To the President of the University:

DEAR SIR: The nineteenth annual report of the Geological and Natural History Survey of the state is herewith presented The larger part of the year was devoted to the preparation and the publication of the report on the iron ores of the state, embraced in Bulletin No. 6, which was finally issued in April, 1891. Into this (accompanying) report are gathered therefore various reports and papers that have accumulated in the progress of the survey, and some lists of specimens and publications, the printing of which will be a great convenience.

Respectfully submitted,

N. H. WINCHELL,

State Geologist and Curator of the General Museum.

CONTENTS.

I.

THE ELEMENTS OF A NEW METHOD OF CHEMICO-MICROSCOPIC ANALYSIS OF ROCKS AND MINERALS.

BY

DR. EMANUEL BORICKY.

(Archives of the Natural History Survey of Bohemia.)
(Vol. III. Part V.)
1877.

NOTE.

This translation is the work of several persons. Begun in 1880 by the undersigned, it was suspended because of the urgency of other duties. It was resumed and carried on in 1887 by his daughter (now Mrs. F. N. Stacy), who in turn surrendered it to Miss Mary Blanchard, and by her in 1889 was finished the first English copy. It has recently been re-compared with the original by Mr. Herbert A. Wood, and a final revision and correction have been made by the writer.

In its present form this work will be constantly useful, not only to the collaborators of the survey in its examinations of the crystalline rocks, but to numerous petrographic students in America who do not have easy access to the original. The work of Boricky must always remain the headlight of any train of similar researches which may follow it—a train which has recently received some important accessions at the hands of Fouqué, Streng, Behrens and Renard. Messrs. Levy and La Croix have, lastly, arranged all of these methods in systematic order in their late work, *Les mineraux des roches* (Chapter VIII), and to this the student is referred.

N. H. WINCHELL.

CONTENTS.

INTRODUCTION.

Like a blazing meteor appeared the microscopic examination of minerals and rocks, in the horizon of inorganology. It created surprise by the sudden insight which it afforded into the internal nature of such minerals as had been subjected in vain to manifold hypotheses as to their differences of composition; it created surprise by its unexpected disclosures concerning the existence and origin of several crypto-crystalline rocks, of the nature of which erroneous ideas had been held for nearly a hundred years before; it illuminated many a crooked way which had been pursued in the science of lithology; but it also supplied means for judging of the genetic relationships of minerals and rocks, concerning which no one before ventured to speak without apprehension of much criticism. Therefore it gave rise to the hope that in it had been found the pathway which would lead to a sure knowledge of the mineral world, though concealed by an apparently impenetrable veil.

This hope, which must have taken possession of most mineralogists and geologists, seemed to come at once into realization, inasmuch as Vogelsang's *Philosophy of Geology*[1] and Zirkel's classic work[2] on the basalts followed, as well as Fischer's critical micro-mineralogical studies,[3] and the pioneer work of Sorby[4], for from this time the investigation of

1. Bonn, 1867.
2. Bonn, 1870.
3. Freiburg, 1869 and 1871.
4. "On the microscopical studies of crystals, indicating the origin of minerals and rocks." *Quart. Journ. of the Geol. Soc. London*, 1858. The microscope had already been used toward the end of the eighteenth century for the determination of isolated portions of crypto-crystalline rocks, by Dolomieu and Flerieu of Bellevue, but powdered rock only was the object under investigation. Thereupon the "schlemm process" with an investigation of the parts separated by "schlemm," was advocated by several French geologists. And this operation employed by Cordier (1815) on an enlarged scale received an important extension in a chemical treatment of the rock-powder. But the first crystalline thin sections which were submitted to the study of their inner structure appeared to be those of chiastolite, which Gerhard (according to Fischer's statement) had investigated, but only in reflected light. William Nicol made the first investigation of a thin section in transmitted light, and proposed a method for the display of thin sections; but a searching study of the nature of the inner structure of minerals was made first by David Brewster, who interested himself particularly concerning the petrological significance of fluid inclusions, and also recognized already the importance of microscopical investigation in polarized light. Brewster may be regarded as the true forerunner of Sorby, although microscopic investigations of minerals and rocks were undertaken before Sorby (by G. Rose, Scheerer, Jensch, Knope, von Rath and others)

minerals and rocks sprang into active life. Microscope and lathe have been accepted and industriously employed as indis pensible implements in the special researches of mineralogists and geologists. Numerous minerals have been examined in respect to their internal structure, by means of this new method of investigation; in various countries the investigation of larger and smaller rock-complexes was begun according to the new method, or individual kinds of rocks united under one name, were subjected to this new test. And in three years the scientific material increased so greatly that Zirkel, in the year 1873, found himself impelled to collect, and make accessible to his co-laborers, the scattered results of these researches on the constitution of rocks and minerals, by means of a splendid text book.[1]

But the scientific effort which showed itself in so rich a degree in the direction mentioned, led soon to the knowledge that in this path there were yet large gaps which must be filled up or at least bridged over, if a sure step forward would be taken. And in response to this generally felt need, Rosenbusch[2] hastened to place a practical guide in the hands of microscopic mineralogists and geologists, in order to place before their eyes, through the well ordered collection of diagnoses of the rock-bearing minerals, as far as at that time possible, a clear picture of the territory then known, and in an indirect way to make evident to them the uncertain spots and the gaps.

The next result of these endeavors was a work in the micro scopic research of minerals and rocks, elevated high above the common level, which substantially enriched our knowledge in many directions, especially in respect to the micro-structure of rocks. It gave, however, occasion for many complications, in that often in place of positive results, only the old pillars of knowledge were overthrown and the insufficiency hitherto, of our means for new structures either public or private was shown, or in that only temporary buildings were erected upon the old foundations.

It would be reasonable—certainly in the light of the startling variety which Zirkel brought to notice in the basaltic rocks—to expect that there would be considerable difference also in other rocks heretofore united under one name, and that perhaps there would inevitably appear in respect of some

1. The microscopic structure of minerals and rocks. Leipzig, 1873.

2. Microscopic Physiography of the petrographically important minerals. Stuttgart, 1873.

kinds of rocks, a separation into many species, and in other kinds a union of species, but no one dreamed of the difficulties which arose concerning the degree of similarity which is necessary for the embracing of many groups of rocks under a common name, concerning the relations of geological, mineralogical, chemical and structural principles, upon which a natural system of rocks must be based in order to produce harmony. And the cause for these difficulties is, according to my opinion, to be found in general, in the constant extension of our petrological knowledge, in particular, however, in the deficiencies which are found in our microscopic methods, and which make their employment difficult or uncertain, often permitting only a subjective conception of the object under investigation.

Among these difficult (because incomplete) relations, Lassaulx undertook, in an excellent accurately compiled textbook,[1] devoted especially to the first work in the study of petrology, to bring the results of rock researches known up to that time into systematic order. But if one turn over the leaves of this text-book, suitable to any case, and go through the microscopic diagnosis of individual minerals and rocks, he will be led involuntarily to the above mentioned conclusion, that there is yet much to be accomplished upon the path leading to the right end, before a secure and easy advance towards it will be possible.

If we bear in mind the present standponti of microscopic rock research as it is set forth in the last mentioned text-book, and in those of Rosenbusch and Zirkel, we are obliged first of all to note great increments to the knowledge of the micro-structure of rocks, the micro-structure and other properties associated with it, of the rock-making minerals;[2] and also in the

1. Elemente der Petrographie. Bonn, 1875.

2. In regard to the knowledge of the micro-structure of minerals and rocks, Zirkel has unquestionably deserved the title of master. His works which appeared before the year 1873 are in his hand-book: "The Microscopic Properties of Minerals and Rocks, Excerped and Cited." And among his later works, those on the composition of Kersanton and the structure of Variolite (Ber. d. köngl. sächs. Ges. d. Wissensch. July 1875), and on Phyllit v. Recht im hohen Venn (Verh. d. naturh. V. d. preuss. Rhl. XXX. (1) should be mentioned. Also to Rosenbusch's above mentioned work in which his earlier works are noted, we have to add—besides his great work "Abhandlungen zur geolog. Specialkarte von Elsass-Lothringen," which I received from his friendly hand during the last few days—a valuable treatise "on the Composition and Structure of Granitic rocks," (Zeitschr. d. d. geolog. Ges. 1876) to which have been added two very important works by M. A. Michel Lévy (Structure microscopique des roches anciennes. Bull. soc. geol. France (3)III. 199-236, 1874. and Mémoire sur les dévers modes de structure de roches éruptives. Paris (Dunod, éditeur) 1875, relating to the same subject. Besides Sorby's already mentioned pioneer work, the following treatises of the same

application of those optical properties which are connected intimately with the laws of individual systems of crystals, to the microscopical study of rocks there are (through the efforts

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author should be noted; On the microsc. struct. of Mount Sorrel Syenite etc., Geol. and polytechn. Soc. of the West Riding of Yorkshire 1863; on the microsc. struct of the meteorites, (Proceed. Roy. Soc. London 1864); on the structure of Rubies, Sapphires, Diamonds and some other minerals (Proceed. Roy. Soc. London, 1869).

Contributions by other investigators have been made concerning the knowledge of the micro-structure of individual minerals and rocks, of a late date: Allport (Phon. vom Wolf-Rock. Geol. Mag. N. 84; Pechstein v. Aran, Geol. Mag., 1872, IX. Brit. Dolerite, Qaurt. J. of the Geol. Soc. London, 1874), Anger (Klast. Gest. Tschermack's Mineralog. Mitth., 1875), Artopé (Trachyte der Anden. Diss. Berlin, 1872), Behrens (Grünsteine. N Jahrb. 1871; Opale. Wien. Akad. 1871), Berteles (Ein neues vulk. Gest. Diss. Würzburg, 1874), Cohen (Geogn. petrogr. Skizzen a. Südafrika. N. Jahrb. 1874), Credner R. (Grünschiefer v. Hainichen in Sachsen. Schieferthone u. Thone. N. Jahrb. 1875), Dana (Trap Rocks of the Connecticut Valley. Proceed. of the Amer. Assoc. for the Adv. of Science, Hartford meeting, 1874, N. J., 1875), Dathe (Diabase. Dissert. Serpentine u. Eklogite d. saechs. Granulitgebietes. N. Jahrb., 1876). Doelter (Trachyte des Siebenbürg. Erzgeb.; Trachyte v. Tokaj-Eperies. Tschermak's Min. Mitth., 1874; Melaphyre Südost-Tirols Jahrb. d. geol., Reichsanst. Wien, 1874, u. Tsch's Min. Mitth., 1875), Haarmann, Melaphyre, Diss. Leipzig, 1872), Hebenstreit (Urgest. d. nördl, Schwarzwaldes. Dissert. Würzburg. 1877), Emons (Phon. d. Veley u. Westerwaldes, N. J., 1875), Fouqué (les inclusions vitreuses renf. d. l. feldspaths des laves de Santorin; une ponc de Vesuv; les nodules à oligoklas des laves de Santorin; wollastonit, fassait, grenat des laves de Santorin; les laves des dykes de Thera. Comptes rendus de l'Acad. de Sc. Paris, 1873-1876), Geinitz (Grünsteine d. Saechs. Erzg. Tsch's Min. Mitth., 1876), Gümbel (Palæol. Eruptgst. d. Fichtelgeb. München, 1874. Geogn. Mitth. a. d. Alpen. Sitzgsb. d. k. bayr. Akad., 1877). Hull (Irische Granite. The Geol. Mag., N. J., 1874; Report on the Chem. Min. and Microsc. characters of the lavas of Vesuvius, from 1631-1868. N. J., 1876), Inostranzeff (Vesuvlaven v. Spt., 1871, Maerz u. Apr., 1872; Kalksteine u. Dolomite, Tsch.'s Min. Mitth., 1872), Kalkovsky (Felsite u. Pechsteine Sachsens, Tsch.'s Min. Mitth., 1874; Felsitphorphyre b. Leipzig, N. J., 1875; Salit., etc., Tsch.'s Min. Mitth., 1875; Glimmertrapp v. Melzdorf, 1875; grüne Schiefer Niederschlesiens, N. J., 1876; Einige Eruptgst. d. sæchs. Erzgeb. N. J. 1876), Kenngott (Obsidian, Petersburg. 1869 u. 1870), Koch (Donautrachytgruppe n. Budapest, N. J. 1877), v. Lassaulx (V. Gest. d. Auvergne, N. J. 1869-1872. Hemithrène d. Dep. Puy de Dôme, N. J. 1874. Eruptgst d. Vicentinischen, Z. d. d. geol. Ges. 1873), M. Lévy (Observ. sur. l' origine des roches eruptives. Variolité de la Durance, Acad.; Kersanton. Bull, de la soc. géol. de France, 1876), Liebe (Diabase d. Voigtlandes, N. J. 1870), Lossen (Porphyroide d. Harzes. N. J. 1877), Möhl (Sababurg; Scheidsberg b. Remagen; Bühl b. Weimar; Südwest. Ausläufer des Vogelsgeb; Basalte der rauhen Alp.; Bas. u. Phon. Sachsens; Bas. der preuss. Oberlausitz; Hauynbas. in Hessen; Gest. Thüringens. N. J. 1871-1875); Neminar (Erupgest, v. Banov in Mähren, N. J. 1877), Niedzwiedzki (Banater Eruptgst. Tsch.'s Min. Mitth. 1873) Petersen (Grünsteine, N. J. 1872), v. Rath (Monzoni. Bonn. 1875; Syenitgeb. v. Ditró, Trachytgeb. Hargitta., etc. Bonn. 1876. Geol. Reise n. Ungarn. Bonn. 1877), Rénard u. de la Vallie Poussin (Mémoire sur les caractères min. et stratigr. de roches plutoniennes de la Belgique et de l' Ardenne Française. Acad. roy. Bruxelles, 1876), Rothpelz (Devon. Porphyroide Sachsens, N. J. 1877), Rutley (On some struct. in Obsidian, Perlite and Leucite. R. Microsc. Soc. 1876. Structure d. Feldsp., N. J. 1876), Sandberger (Neph. v. Katzenbuckel, N. J. 1869; Bas. u. Dolerite. N. J. 1870; Apatit im Olivinfels, Tachylyt v. Saesobühl, N. J. 1871; Kryst. Gest. Nassau's. Phys. u. Med. Ges. zu Würzb. 1873; Dolerit. Sitzb., d. k. bayr. Acad. 1873), Sauer (Phon. d. canarischen Inseln, N. J. 1876), Steenstrup (Om de Nordenskiöldske Jaernmasser og om Forekomsten af gedigen Jaern i Basalt Kjöbenhavn. 1876 u. N. J. 1887), Stelzner (Labradorit u. Pegmat. Berg-u. Hüttenm. Z. XXIX), Streng (Feldspathstudien, N. J. 1871; Porphyrite v. Ilefeld, N. J. 1875; Kryst. Gest. v. Minnesota, N. J. 1877), Törnebohm (Diabas u. Gabbrogest, Schwedens, N. J. 1877), Tschermak (Porphyrgest. Oesterreichs, Wien. 1869; Meteorit v. Lodran, Pogg. Ann. 1870. Meteorstein v. Goalpara, Wien, Acad. 1870; Pyroxen u. Amphibol, Min. Mitth. 1871. Meteoriten v. Stannern, Constantinopel, Shergotty u. Gosalpur, Min. Mitth. 1872), Umlauft (Thonschiefer, Lotos, Prag. 1876), Vogelsang (Flüssigkeitseinschlüsse in gewissen Min.

of Zirkel and Rosenbusch,) important advances to be noted.[1] There were indeed, important attempts made to determine individual species of certain groups of minerals, merely by means of optical properties. Tschermak[2] first alluded to the fact that the observation of pleochroism and light absorption rendered important service to the separation of individual branches of the amphibole and biotite groups; and later Descloizeaux showed how a member of the feldspar group can be identified with certainty by the determination of the position of the chief direction of oscillation in the known thin section of a feldspar by placing it in the maximum extinction of light between crossed Nicols[3].

Accordingly through excellent publications very important advances have been made in modern petrology by means of the employment of the morphological and optical properties of minerals; but the chemical laboratory which should reveal to us in the thin sections of the mineral its uniform and permanent characters by the results of certain tests seems—unfortunately for modern petrology—to refuse its aid. Noteworthy attempts have been made, it is true, in the latter direction and methods have been proposed for the determination of some rock-forming minerals in minute tests or thin sections, but these were either limited to a very few minerals or in their applications were of no special importance.

Indeed Zirkel, in his experiments upon the basalts has frequently proved the insolubility of the minerals in acids, by boiling the powdered rock in muriatic acid. By other investigators thin sections were boiled in muriatic acid or treated with cold muriatic acid; many important phenomena were

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Pogg. Ann. 1869; Krystalliten, hrsg. v. Zirkel. Bonn. 1874), Voldrich (Hercyn-Gneissformation, Jahrb. d. k. k. geol. Reichsanst. Wien. 1875), Vrba (Gest. Grönlands. Wien. Acad. 1875; Grünsteine, a. d. Adalberti-Sch. v. Pribram, Oest. Z. f. Berg. u. Hüttenw. 1876), Zinckendrath (Kersanton v. Langeuschwalbach. Würzburg. 1875). In conclusion, I think that my works in relation to the Basalt, Phonolith and Melaphyrgesteine of Bohemia ought to be mentioned (Archiv. d. naturwiss. Landesdurchf. v. Böhemen, 1873, 1875 u. 1876).

1. Very noteworthy are Rosenbusch's observations in his description of the new microscope for mineralogical and petrological researches. N. Jarhb, f. Min., 1876.

2. Sitzb. d. k. Akad, d. W. in Wien, B. LIX. 7 Abth., 1869.

3, Examen microscopique de l'orthose et des divers feldspaths tricliniques. Comptes rendus des séances de l'Academie des Sciences LXXXII,: seance du 1er Mai, 1876. Memoire sur les propriétés optiques biréfringentes caracteristiques des quartre principeaux feldspaths tricliniques, et sur un procédé pour les distinguer immédiatement les unns des autres. Ann. de Chim. et Phys., IV.; 1875.—Memoire sur l'existence, les propriétés optiques et cristallographiques, et la composition chimique du microcline, nouvelle espèce de feldspath triclinique á base de potasse, suivi de remarques sur l'examen microscopique de l'orthose et de divers feldspaths tricliniques. Amn. de Chimie et de Phys., IX: 1876.

noticed, such as effervescence, separation of gelatinous silica, and the solution and removal of turbid secondary products.

Since, however, for the determination of the insolubility of a mineral in acids, no fixed law was decided upon, other than the carrying out of the same experiments under exactly similar conditions, different results were often obtained upon the same materials by different investigators, or the similar results were interpreted differently.[1] And the result was that, instead of establishing the conditions (specific gravity of the muriatic acid used, and length of treatment), under which the action of the acid should be exerted, distrust was aroused against this very reaction—which was susceptible of being used to a considerable extent, and successfully, especially upon thin sections—and thus its application became limited to the most necessary cases. So now, for example, this reaction is very little used for the approximate determination of individual members of that feldspar group, for which the comprehensive term, "plagioclase," is preferred.

Rosenbusch endeavored to introduce some operations, customary in analytical chemistry, such as the formation of precipitates, and their separation from the substances remaining in solution, by means of a filtering apparatus (under air pressure);[2] but his efforts appear to have had little result. Moreover the etchings which appear upon the various surfaces of minerals treated with dissolving reagents and which bear an intimate relation to the morphological character of the mineral, were hopefully alluded to; but,—although, except Leyden's[3] experiments upon quartz, Knopp's[4] upon xanthophyllite and Sohnke's[5] upon sodium chloride, a series of minerals[6] were investigated by Baumhauer in regard to their etchings—as to

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1. In order to furnish an example, the following passage to be found on page 407, the 18th line from top, in Zirkel's Handbook, "The microscopical properties of minerals and rocks," may be cited. Through treatment with hydrochloric acid the plagioclase of diabase is strongly attacked and exhibits after this action on the polariscope no more lamellar banding. In a similar manner Senfter distinguishes the oligoklase nature of most feldspars, though he has observed (p. 602) of oligoklase, that by long digestion in hydrochloric acid it is as good as not affected.

2. N. Jahrb. f. Min. etc. 1871. 914.

3. Sitzb. d. k. Akad. d. w. in Wien XV. 1855.

4. N. Jahrb. f. Min. 1872. 785.

5. N. Jahrb. f. Min. 1875.

6. The etchings on crystals. N. J. f. M. 1875. (190).
Upon potassium-mica. granite, cobalt-quartz. N. J. f. M. 1875. (192).
Upon magnesia-mica and epidote. N. J. f. M. 1875. (420).
Upon apatite and gypsum. N. J. f. M. 1875. (746).
Upon lithia-mica, turmaline, topaz, zinc-silicate. N. J. f. M. 1876, (1).
Upon adularia, albite, fluorite, and chlorides of natron. N. J. f. M. 1876. (602).

their value in petrology no decided advance has thus far been made.

Very note-worthy also are those methods which have for their object the separation of individual minerals from the mixed crystalline rocks and their chemical analysis—such as Müller's separation of quartz and some silicates from each other by means of phosphoric acid hydrate,[1] Gümbel's "meal test"[2] and Fouque's method of separation of ferruginous portions from the non-ferruginous by means of a strong electro-magnet and by means of concentrated fluohydric acid[3]—but all these experiments are tedious and demand much material, which, when converted into powder, and the homogeneous mass of separated mineral particles is examined, admit no such minute microscopic observation as a mineral cut through in a thin section.

I consider Knopp's micro-chemical reaction[4] upon members of the hauyne family as quite simple and practicable. By this method for the first time a vaporous substance, (sulphur vapor) is converted into the constant character of a determined mineral of a thin section, viz., the blue color of a hauyne-like mineral and to the black of an iron holding mineral. Just as practical is the application of molybdate of ammonia for the proof of phosphates in thin sections, and especially for the separation of apatite from nepheline, which reaction was introduced by Streng.[5]

In conclusion Szabo's *Neue Methode, die Feldspathe auch in Gesteinen zu bestimmen*[6] deserves special notice, since by careful observation of certain experiments on small fragments of feldspar the size of a poppy seed, it makes effective the old known methods, especially those for determination of the melting point, and of the flame reaction for sodium and potassium. For the experiment by the gas flame it requires many appliances and considerable practice. According to Szabo's report, his five stages of the sodium flame show: 0.3–1 per cent, 1–2 per cent, 2-4 per cent, 4–8 per cent, 8–16 per cent of sodium, and the four stages of the potassium flame: 0.3–1 per cent, 1–4 per cent, 4–13 per cent, and 13–22 per cent of potassium.

1. Journ. f. prakt. Chemie XCV, (43) and XCVIII, (14).

2. Volcanic rock of Fichtelgebirges, München, 1874.

3. Nouveaux procédés d'analyse médiate des roches, etc. Comptes rendus 1874, XXII, (11).

4. N. Jahrb. f. Min. etc., 1875, (74).

5. Tschermak's Min. Mitth. 1876.

6. Budapest, 1876. From the Hungarian original, published by the Hungarian Academy, d. w. 1873.

Though I gladly availed myself of the chance of reading Szabo's book, when its title page met my eye, yet, after a painstaking study of it I was obliged to lay it aside unused, because my small private laboratory does not support the luxury of gas-lighting, and at the University in this place neither a laboratory nor any such means of help is at my disposal. Nevertheless, I found myself compelled to seek another way to the same end, *i. e.*, the determination of the feldspars, and the ability in my future work to eliminate the expression, so much cherished in modern petrology, "plagioclase," by means of the accurate designation of the feldspar group.

I first turned my attention to the pure feldspar, but after a series of experiments which I began in August of last year, I extended my work to all minerals which contained alkalies or alkaline earths, and became convinced that my method could be applied not only to the determination of the most minute mineral fragments, but also under the same circumstances, to the determination of minerals in thin sections of cryptocrystalline rocks.

When I had become convinced that in the most common operations in analytical chemistry, for example, the formation of successive precipitates, filtering, decanting, etc., not much is to be accomplished in the substantial investigation of minerals in thin sections, it occurred to me to cause special gaseous material (as hydrofluoric gas, chlorine gas) and such liquid substances as continually volatilize (as hydrofluosilicic acid), to act upon thin sections of minerals, and to utilize the substantial changes which present themselves upon the upper surfaces of thin sections and admit of a microscopic investigation, to the determination of minerals.

First of all I thought of the etchings of crystallographically determined mineral sections, then upon the successive removing and separate investigation of individual new-formed products, through various solvents and reagents; but the observation of beautiful, characteristic crystals which appear on some specimens, soon taught me that a far more important role is to be attributed to the new products formed from the investigated minerals—so far as they can be obtained in easily recognized crystal forms and as far as the individual chemical mineral elements, especially those of the alkalies and alkaline earths, can be investigated by these crystals and determined according to their quantitative relation—since by this means,

results are to be obtained in the shortest and most convenient way (for those who are not expert in chemical operations), while for the same results analytical chemistry requires much time and experience.

The first substance which I used was hydrofluoric gas. I was convinced that by its action upon alkaline silicates, silicicfluorides of the alkalies would be formed, which, dissolved in boiling water, can by the evaporation of the solution be obtained in the characteristic crystals, differing for potassium and sodium. I thus saw the possibility realized of being able to separate with great readiness and in the smallest specimens all silicates containing potassium from those containing sodium, especially potassium feldspars from the soda and lime feldspars, and in general alkaline from non-alkaline silicates. Besides this there appeared some accompanying phenomena which seemed to me to be important as means of recognizing the minerals. Thus, for example, I saw that besides the alkaline silicates a long series of non-alkaline silicates is affected by hydrofluoric gas, and that all those minerals from which fluorides are formed can be easily recognized by effervescence in sulphuric acid (which can be easily observed in the microscope); I saw that in the sections of phonolite treated with HF and then boiled in water, Möhl's nepheline-glass was reduced to rather sharp edged sections of nepheline, that through similar treatment wholly turbid as well as very thin sections of porphyry became perfectly clear and bright, and thus their mineral composition and that of similar minerals could be easily recognized.

But the original problem of this work, the determination of those groups of the feldspar family which we unite under the names of oligoclase, andesine, labradorite and anorthite, could not for a long time be solved in a simple way. After I had established the fact through experiments that from the soda-lime feldspar treated with HF, all the alkalies are dissolved as silicicfluorides, by boiling away in water, while the greater part of the calcium remains behind in the specimen either as a fluoride or as an aluminous lime fluoride,[1] I struck upon several ways of reaching the desired end, that is, for determining approximately the quantitative proportions of calcium and sodium in the feldspars, which ways proved more or less suc-

1. If the silicicfluoride of calcium had been formed, it would as one of the most readily soluble silicicfluorides, have been quickly and perfectly dissolved in the water.

cessful, but none of which satisfied me on account of their minuteness.[1]

Naturally it occurred to me to produce in the form of silicicfluorides the sodium as well as the calcium of the lime-soda feldspars, since the artificial salts of both elements showed various, easily distinguished crystal forms; then my attempt went so far as to change calcium fluoride into silicicfluoride. For this end I treated the specimens changed by HF with hydrofluosilicic acid, but I found to my sorrow that the silicicfluoride crystals from sodium were always to be found in a considerably larger quantity than the proportion for the calcareous feldspars demanded. And for this reason I suspected that in the indicated proportions a considerable portion of the silicicfluoride of calcium crystallizes in the same form as the silicicfluoride of sodium.[2]

Since I intended to seek for the reason of the similar crystallization of substances appearing elsewhere in various forms, in the similar conditions of solution under the circumstances named, I simplified the investigation by treating the specimen directly with hydrofluosilicic acid in order to bring the very soluble silicicfluoride of calcium to formation and solution more quickly than the less soluble silicicfluoride of sodium. And these experiments had the desired result in that they demonstrated a decided difference in the silicicfluoride forms of potassium, sodium, calcium (eventually strontium), magnesium (eventually iron, manganese), occasionally also of lithium and barium, as well as made possible a quite easy separation of them. Besides this, my efforts went so far as to make known the reactions for the silicicfluorides similar in their forms to the individual elements named, in order to acquire complete knowledge of their substantial differences even in doubtful cases.

The use of chlorine gas as a reagent offered many advantages, thus: For the proof of insolubility in acids, for the proof of alkalies, for producing the characteristic etchings (in some minerals), especially, however, for establishing whether the silica which separates out of the thin section of a silicate is gelatinous or granular. And of the older methods that of

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1. I reported these methods in the session of the mathematical and physical science classe d. k. böhm. Gesells. d. w., on Nov. 10, 1876.

2. From treatment with sulphuric acid were formed many of those broad monoclinic crystal needles, formerly only the peculiar silicicfluoride forms of sodium, which I took for the formtypes of gypsum crystals.

heating the specimen showed itself in most cases applicable to the recognition of the coloring metals, and to the approximate determination of the melting point, and that of the clay reaction by means of cobalt solution with microscopic investigation, to the thin sections of different kinds of rocks.[1]

Since I already use the methods explained here, though probably capable of further development, in those studies whose publication is reserved to the archives of the general scientific investigations of Bohemia, I consider this little book as an introduction to my further petrological work, and herewith venture to justify its insertion in the archives of general scientific investigation.

In conclusion the pleasant duty remains to me to express my warmest thanks to my highly esteemed colleague, Prof. Stolba, for furnishing me with a quantity of chemically pure silicic acid which was necessary for my experiments, and for his advice concerning the latter.

1. Upon all these methods I have already made communications in the session d. k böhm. Gesells. d. w. on Feb. 9 of this year.

I. General Method for the Micro-Chemical Determination of the Metals of Petrologically Important Minerals by means of Hydrofluosilicic Acid.

Principle of the Method.

With the exception of a few which offer the greatest resistance to chemical reagents, all minerals which contain alkalies, alkaline earths, heavy metallic monoxides (or analogous sulphur, selenium, tellurium, arsenic, or antimony compounds) are more or less affected by strong hydrofluosilicic acid.

The result of this action is the formation of silicicfluorides (from the metalic elements of the minerals and the hydrofluo silicic acid), which dissolve in the hydrofluosilicic acid solution and after the evaporation of the solution make their appearance in beautifully formed crystals (or of small groups of them) characteristic of the individual elements.

If the treatment of a very small piece of mineral with hydrofluosilicic acid is performed upon a spot on the object glass coated with thoroughly boiled Canada balsam, the silicicfluorides thus formed can, even in their minuteness, be studied, magnified to any desired degree.

If the silicicfluorides of the individual metals, which are formed upon the object-glass under the conditions mentioned could be separated from each other, either through the different crystal systems to which they belong, or through definite, easily recognized typical forms, or through characteristic changes when treated with new reagents, perfectly reliable means for distinguishing the individual metals would thus be afforded.

Of the silicicfluorides, thus far known, of the metals appearing in petrologically important minerals, those of potassium, cæsium, and rubidium belong to the tesseral crystal system, and those of sodium, magnesium and iron to the hexagonal or hemihedral-hexagonal system, while those of lithium, calcium and strontium (according to Marignac's statement) must be monoclinic.

In the determination of a petrologically important mineral it is hardly of importance to prove the presence of cæsium and rubidium with potassium.

The silicicfluorides of sodium, magnesium and calcium produced under the conditions mentioned show such different forms that they can, in most cases, be distinguished at the first glance. Moreover the silicicfluolithium crystals, produced from lithia-mica and lithia-iron-mica are so peculiar as to be quite easily identified; but silicicfluostrontium presents almost the same crystal appearance as silicicfluocalcium, and in nearly the same forms in which silicicfluomagensium appears; we find also silicicfluorides of iron and manganese; so that a separation of the silicicfluoride of calcium from that of strontium and of magnesium from those of iron and manganese would scarcely prove successful.

But the separation of the last named metals in the forms of silicicfluorides is not rendered impossible on this account; for by treating them with new reagents the desired end is quite easily reached.

If, for example, silicicfluocalcium and silicicfluostrontium are treated with dilute sulphuric acid, the crystals of the first are, after a few seconds, surrounded by a thick beard of monoclinic gypsum needles, while the crystals of silicicfluostrontium very slowly (in several hours) liquify into a granulous mass, or only very short (celestine?) needles, are here and there observed. In the same way can the silicicfluorides of magnesium, iron and manganese be separated by the application of various substances. The application of chlorine gas is worthy of recommendation, by means of which the silicicfluoride of iron assumes an intense citron-yellow color, while silicicfluomagnesium and silicicfluomanganese remain almost colorless: yet the manganese salt has a streak of red, and appears strongly agglutinated, and for the most part changed into a group of little tablets, prisms and melted grains, although the crystal forms of silicicfluoride of magnesium appear to be changed a little.

Also the application of sulphide of ammonium vapor for the separation of the last-named metals in the form of silicicfluorides produces exactly the same results.

From these experiments it can be seen that the metals appearing in petrologically important minerals in the presence of hydrofluosilicic acid may be easily identified. At the same time, moreover, the quantitative proportions of the several

metals existing in a mineral can in most cases be approximately ascertained.

If the mineral is readily acted upon by the hydrofluosilicic acid all the metals in their variously formed silicicfluorides make their appearance after the evaporation of the solution, and, indeed, (if they do not materially differ in their conditions of solubility) in about the same quantitative proportions in which they existed in the mineral investigated. If, however, the mineral to be analyzed is only slightly attacked by the hydrofluosilicic acid, the latter has acted on the greater part or the whole of that metal (of the respective metals) which can be most easily dissolved, while for the other metals of the same mineral only small silicicfluoride crystals or none at all are observed.

The conditions of the silicicfluorides in solution must, consequently, be considered, as well as the comparison of the quantitative proportions of the silicicfluorides, with the quantitative proportions of the metals contained in the original minerals.

If from several metals which the mineral under investigation contains, at the first treatment with hydrofluosilicic acid only one makes its appearance, then the treatment of the same portion of mineral is to be repeated with fresh hydrofluosilicic acid, which treatment usually produces the wished for result; that is the making visible of the remaining metals in the form of silicicfluorides. It is evident, however, that in this fortunately rare case the quantitative proportions of the silicicfluorides will not correspond with the proportions of the metals which the chemical analysis of the mineral demands, but that, for approximate determination of the quantitative relations of individual metals in the mineral to be examined, other methods, to be explained later, must be employed or special experiments (with hydrofluosilicic acid) must be established as rules for these individual minerals,

It may be remarked here that thin sections are more readily acted upon than cleavage particles or broken fragments.

In conclusion I think I may say that clay, and sesquioxides in general, and minerals which are free from monoxides, afford when treated with hydrofluosilicic acid, no new formed products in crystal forms.

EXECUTION OF THE METHOD.

Place a few drops of Canada balsam upon an object-glass and hold it over a spirit lamp until the little bubbles which form have passed off, and the balsam acquires, after cooling, a firm, resinous consistency. At the same time try so to turn the object-glass while the balsam is still liquid, that it will form in hardening as thin and even a coating as possible upon the glass.

In the middle of the balsam layer place the specimen or thin section of the mineral to be examined, and again heat the object-glass, but only enough to cause the specimen to adhere firmly. If the specimen is a thin section, let it be as thin as possible, because it loses something of its transparency by reason of the crust of silicicfluoride; then it must be heated cautiously (to prevent the formation of little vesicles), and carefully pressed with a penknife so that no little gas bubbles remain under it and that it may assume a perfectly horizontal position,

The size of the specimen is entirely arbitrary. It may be the size of a pea, or it may be a very much smaller piece; yet it is advisable to keep a certain relation to the size of the drop of hydrofluosilicic acid which is to be put upon it.

I usually take a specimen of mineral about the size of a pin-head or a millet grain, and place upon it a drop of hydrofluosilicic acid of about the size of a pea, If two or more pieces of minerals are taken of the above mentioned size, the drops of acid must be increased in a proportionate degree. I take a thin section of the size of 4–6^{mm}, taking care that the hydrofluosilicic acid placed upon it does not spread over the section, but that the drop maintains the greatest height possible, so that the greatest depth of fluid may work upon the smallest surface.

If one has to investigate a mineral dissolved in water it is advisable to take a larger amount than the above mentioned relation to the quantity of acid required, because, besides the silicicfluoride of the metal which is contained in the specimen, the crystal form of the specimen itself (either of the unchanged mineral or of its individual salts) is also brought to perfection, and one has a complete analysis of the mineral before his eyes. For example, if the specimen were a sodium salt, such as sodium-chloride, sodium-nitrate, mirabilite or borax, from each substance would be obtained short hexagonal prisms of silicicfluoride of sodium, but besides this in the first specimen little cubes of sodium-chloride, in the second rhombohedrons of so-

dium nitrate, in the third monoclinic needles of glauber salt, and in the fourth borax crystals easily recognized by their form; but from polyhalite one would find near the fluorides of the individual metals little crystals of gypsum, etc.

The hydrofluosilicic acid applied must be perfectly pure so that no silicicfluoride crystals be left upon the balsam plate of the object-glass when dried. The hydrofluosilicic acid prepared according to the direction of the analyst[1] is useless for our purpose for the reason that it is prepared and preserved in glass vessels so that it already contains various silicicfluorides, (whose metals come from the glass).

The hydrofluosilicic acid which I used was prepared by my assistant, Mr. Plaminek, by the introduction of fluosilica, obtained from fluoride of barium, sulphuric acid and pure quartz powder in a lead retort, into a platinum crucible filled with water, and this after moderate dilution was decanted in a caoutchouc flask for preservation. For transferring the drop of hydrofluosilicic acid upon the specimen (situated upon the balsam surface of the object-glass) I use a caoutchouc stick. which has a spoon-shaped rim upon the end, which may be used in dipping.

In regard to the strength of the hydrofluosilicic[2] acid, the following should be taken into consideration: If the acid is too weak most minerals are not acted upon at all, or only slightly; if it is too strong, then so many silicicfluorides will be formed, and, in addition, from the silicates so much silicious earth will be separated, that the field of vision becomes entirely dark or opaque, and no crystal forms can be distinguished—thus it is, for example, with a thin section of elæolite. In such a case the difficulty is easily remedied if one or two drops of water are added to a drop of hydrofluosilicic acid of the same size as before, for a new trial.

According to Mr. Plaminek's statement my hydrofluosilicic acid is about 3½ per ct. strong. And this attacks thin sections of albite, orthoclase, muscovite, tourmaline, and pleonaste, and causes the formation of silicicfluorides.

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1. Anleitung zur qual. chem. Analyse. Fresenius, 1866, page 51. Und Stolba. Ueber die Bereitung der kiesel flussaure im Kleinen. Dingler's polytechn. Jour. B. CXCVII. page 336 (1870).

2. Stolba (J. f. prakt. Chemie XC, 193) has designed, upon the basis of two series of experiments, a table upon the specific gravity of dilute hydrofluosilicic acid of different values (to 34 per ct.). He finds that the specific gravity increases regularly for every half per ct. Thus at 17.5°, for hydrofluosilicic acid of

	0.5 per ct.	1 per ct.	1.5 per ct.	2 per ct.	5 per ct.	10 per ct.
the specific gravity is	1.004	1.008	1.012	1.016	1.0407	1.0834

When the specimen has been treated with hydrofluosilicic acid, bring the object-glass (holding it always in a horizontal position) to a level place quite free from dust, and cover it with a tumbler or inverted glass under which has been placed a little cup of sulphuric acid. I place the object-glass with the specimen and acid upon the perfectly even and horizontal surface of a rather large mahogany chest, but must wait twenty-four hours for the complete drying of the drops, although in perfectly dry air only a few hours would be required.

A brief resumé of the detail of the operation may be given in the following words: The specimen placed upon an object-glass previously coated with a layer of balsam, is covered with one or two drops of hydrofluosilicic acid and allowed to lie intact and in perfect rest in a horizontal position and protected from dust until the drying of the drop is accomplished. And this entire preparatory work requires hardly five minutes time.

When the drop of hydrofluosilicic is dried the preparation is ready for microscopic examination.

MICROSCOPIC CHARACTERS FOR THE DETERMINATION OF THE SILICICFLUORIDE FORMS OF THE METALS APPEARING IN PETROLOGICALLY IMPORTANT MINERALS.

(*Developed by hydrofluosilicic acid.*)

The metals appearing in minerals of petrological importance are potassium, (cæsium, rubidium), sodium, lithium, calcium, strontium, barium, magnesium, iron and manganese.

The silicicfluoride of potassium (K_2SiF_6) (Plate I, Fig. 1, a, i) prepared from orthoclase, microcline (Plate I, Fig. 2 and Fig. 16), leucite (Plate II, Fig. 2), muscovite (Plate II, Fig. 5, at the right), biotite (Plate I, Fig. 1, e, m, n, r)* and some other minerals,[1] magnified to four hundred times the original size, appeared always in sharp-edged crystals with smooth surfaces and usually small. These crystals belonged to the tesseral system and always remained dark between the crossed herapatites.

1. Saltpeter, sylvine, potassium-alum.

*In this translation the English letters are substituted for the Greek, viz.: *a* for alpha, *e* for epsilon, *i* for iota, *s* for sigma, *n* for nu, *m* for mu, *r* for rho, etc.

The most common form was the hexahedron whose little crystals were occasionally united[1] in pretty chandelier-like groups; quite frequently the combination forms ∞ 0 ∞ .0; or ∞ 0. ∞ 0 ∞ made their appearance, the latter especially when the specimen had been treated first with fluohydric gas and then with hydrofluosilicic acid.

Upon the imperfect development of the larger crystal forms the surfaces appeared in the form of steps or displayed a beautiful structure of scales.

According to Marignac[2] and Stolba[3] the silicicfluoride of potassium crystallizes in octohedrons (probably from the pure water solution).

According to Stolba's statement one part of silicic fluoride of potassium requires 833.1 parts of water at a temperature of 17.5° and 104.8 parts of boiling water.

In hydrochloric acid this silicicfluoride is the more soluble the stronger the acid is: for according to Stolba's experiments[4] HCL of the strength of 26.5, 14.1, 9.6, 2.7, 1.8 per cent. dissolves of silicicfluoride of K 237, 340, 357, 376, 409 parts, at the temperature of 14 degrees.

At 17.5 degrees the specific gravity of this fluoride is 2.6655 —2.6649.[5]

The silicicfluoride of sodium (Na_2SiF_6) (Plate I, Fig. 4), prepared from albite (Plate II, Fig. 1), pericline, the oligoclase feldspars (Plate I, Figs. 17-19), nepheline (Plate II, Fig. 3), scapolite (Plate II, Fig. 4), and several other minerals,[6] appeared always in short hexagonal prisms which were either terminated by basal planes or more frequently by a blunt pyramid, and whose vertical edges were often truncated

1. Beautiful groups of this kind were obtained from the aqueous solution of feldspathic mixed portions of syenite from Plauenschen Grunde, near Dresden, and of amazonite from Miask, when treated with fluohydric gas. (Plate I, Fig. 2.)

2. Comptes rendus, xlv, 650.

3. Jour f. prakt Chemie. xc. 193.

4. Jour. f. prakt. Chemie, ciii, 396.

5. The silicicfluoride of cæsium (Cs_2SiF_6) crystallizes from a dilute solution (through voluntary evaporation) into cubes with truncated corners. At 17 degrees it dissolves in 166 parts of water and more easily in hot water. In alcohol it is insoluble. (*C. Preis. Jour. f. prakt. Chemie.*, ciii, 410.)

The silicicfluoride of rubidium (Rb_2SiF_6) crystallizes in the combination forms ∞0∞.0.∞0, dissolves at 20 degrees in 614 parts of water, and at 100 degrees in 78.8 parts water. In acids it is easily soluble. In spirits of wine insoluble. Its specific gravity at 20 degrees is 3.3383 (*Stolba. Jour. f. prakt. Chemie.* cii. 1).

The silicicfluoride of thallium, prepared by treating the carbonate of thallium monoxide with hydrofluosilicic acid and evaporating the solution, crystallizes in tesseral, six sided tablets, or distorted octohedrons which are easily soluble in water. (*Gmelin's Handb. d. anorgan. Chemie.*, 1875, *Bd.* 3, *p* 193).

6. Rock-salt, sodium nitrate, borax, cryolite, phosphorus-salt.

by secondary pyramids, ($\infty P2$). Imperfectly formed crystals of silicicfluoride of sodium had barrel-shaped, oval or cylindrical forms.

Between the crossed Nicols appeared all the forms of silicicfluoride of sodium colored yellow or blue; they were all dark except those arranged at right angles with the main axis.

Marignac (Jahresb. über Fortschritte der chemie,) etc., v. Kopp u. Will, 1858, [für 1857], p. 129,) takes the crystals of silicicfluoride of sodium for holohedral forms ($\infty P . 0P . P . \infty P2$) and adds $\infty P : P = 123$ deg. 3 min.

According to Stolba (Jahresb. über Fortsch. d. Chem. etc., 1858 [für 1857] p. 129) one part of the silicicfluoride of sodium requires for its solution 153.3 parts of water at a temperature of 17.5 deg. and 40.66 parts of boiling water; it easily forming an oversaturated solution.

Its specific gravity is 2.7547.

The presence of a larger quantity of silicicfluoride of calcium has a noticeable influence upon the length of the hexagonal prisms of silicicfluoride of sodium. I have prepared three specimens differing in the quantity of both silicicfluorides. In the first specimen were two parts by weight of the sodium-salt, with one part, by weight, of the calcium-salt; in the second specimen equal parts, by weight, of both silicicfluorides, and in the third specimen one part, by weight, of silicicfluoride of sodium and two parts, by weight, of silicicfluoride of calcium The crystals of silicicfluoride of sodium in the second specimen were one-half longer than those in the first, and those in the third were double the length of those in the first. (Plate I, figure 7 and figure 8.)

The silicicfluoride of lithium prepared from the rose-red lithia-mica from Roznau in Moravia, and from a light lithia-iron mica from Zinnwald (Plate II, fig. 5, at the left) appeared, when magnified to 400 times, in minute, sharp-edged, six sided pyramids, which usually presented the appearance of a regular blunt, hexagonal pyramid. At times, however, a couple of surfaces were developed to such an extent, that the other surfaces of the distorted rhombic or rhomboidal forms could hardly be distinguished.

The silicicfluoride of lithium (Plate I, fig. 3) represented from the preparation of Prof. Stolba by recrystallization presented circular forms, notched or undulating at the edge, fibrous, striated within or ornamented by several concentric circles.

Occasionally. by the overlying of imperfectly formed crystal-prisms, these forms appeared to resemble cauliflower buds or blossoms and among them were found many little tablets with a regular six or eight sided appearance, sometimes also, ornamented with concentric inner circles, which remained dark between crossed Nicols. If one should consider the latter hemihedral forms of the hexagonal system, they would be regarded as combination forms of 0R.—R.∞R. and 0R. R.—R.∞R.∞P2. Besides these there were found in the preparation a few very short, hexagonal prisms.

According to Marignac (Ann. Minn. [5], XV, 221)[1] the silicicfluoride of lithium ($Li_2 SiF_6 + 2H_2O$) is monoclinic and appears in the form of combination ∞P.0P.P∞.⅓P∞.—P∞. In the clinodiagonal chief section is ∞P: ∞P=83° 38′, 0P: ∞P=108° 14′, 0P: P∞=96° 36′, 0P:—P∞=139° 42′. The crystals are quite easily cleavable parallel P∞, less easily parallel 0P. They decompose in the air.

According to Stolba the silicicfluoride of lithium may be obtained by evaporating a solution of carbonate of lithium in a slight excess of hydrofluosilicic acid. The salt crystallizes, after voluntary vaporization, in transparent, four-sided, obliquely truncated prisms or irregular six-sided tablets which dissolve at a moderate temperature in 1.9 parts of water, also in alcohol but are insoluble in ether or benzol. Their specific gravity is 2.33.

The silicicfluoride of calcium (Plate I, Fig. 6), prepared from oligoclase feldspar (Plate I, Figs. 17–19), anorthite (Plate I, Fig, 20), wollastonite, amphibole (Plate II, Fig. 7), diallage (Plate II, Fig. 8), scapolite (Plate II, Fig. 4), epidote and other minerals[2], forms peculiar, long, pointed, thornlike crystals, branching and usually spindle-shaped; sometimes, also, in the form of rhomboidal tablets which are often united in star-like or other groups, and in most cases are recognized at the first glance. Many of the spindle-shaped forms are bounded by six lateral planes and terminated by one basal plane so that they appear like very sharp rhombohedrons truncated by basal surfaces. At times they appear very abundant in six-sided forms which resemble pointed rhombohedrons (about—2R of calcite).

A characteristic feature of these crystal forms (of silicicfluoride of calcium) produced by hydrofluosilicic acid from thin

1. Und Jahresber ü. d. Fortschr. d. Chem. 1860 (pro 1859) 107.

2. Calcite, dolomites, polyhalite, anhydrite, gypsum, fluorite-albite, titanite, scheelite.

sections or fragments of mineral is the lack of sharp rectangular edges and smooth surfaces and the presence very often of a peculiar grayish or brownish dusty character, probably because of the inclusion of delicate bubbles.

The silicicfluoride of calcium prepared by Prof. Stolba, forms mostly four-sided, rarely six-sided prisms (Plate I, Fig. 5) and needles which are terminated by an oblique terminal plane or by one prominent and several small oblique planes. These crystal needles are often united in radiated, spherical groups resembling warts.

According to Marignac (Comptes rendus XLVI—854 und Jour f. prakt. Chem, LXXIV—161) the silicicfluoride of calcium ($Ca\ Si\ F_6 + 2\ H_2\ O$) crystallizes in monoclinic, microscopic crystals which are probably isomorphous with silicicfluoride of strontium.

According to the report of my colleague Herr Stolba, and my own experiments, the silicicfluoride of calcium is readily soluble in water.

The silicicfluoride of strontium prepared from strontianite by means of hydrofluosilicic acid, and from the preparation of Herr Stolba by recrystallization, (Plate I. Fig. 9) appears in sharp-edged, smooth-surfaced prisms and needles which can scarcely be distinguished from the crystal forms of silicicfluoride of calcium produced from the preparation of Herr Stolba, except that they occasionally exhibit a greater abundance of planes.

According to Marignac (Jahresb. über Fortschr. d. Chem. von Kopp and Will 1859 [für 1858] pag. 145 u. 1860 [für 1859] pag. 107) the silicicfluoride of strontium ($Sr\ Si\ F_6 + 2\ H_2\ O$) is monoclinic. In the clinodiagonal principal section are $\infty P : \infty P = 84° 16'$ and $0P : \infty P = 103° 13'$.

The silicicfluoride of barium prepared from calciferous witherite (in the form of a microscopic preparation) by means of hydrofluosilicic acid, presents, when magnified fonr hundred times, extremely slender sharp-pointed needles, whose form although sharp-edged and smooth-surfaced is very hard to determine on account of the minuteness of the crystals.

According to Stolba (Jour f. prakt. Chemie XCVI. 22) the silicicfluoride of barium presents microscopic elliptical, cruciform, divergent and roundish groups. Prepared from a dilute solution slowly evaporated it appears in slender needles.

One part of silicicfluoride of barium requires for solution, according to Stolba, 3731 parts of water at a temperature of

17.5°, 3313 parts at a temperature of 21° and 1175 parts of boiling water. It is easily soluble in acids and in salts—namely, in 448 parts 4½ per cent muriatic acid and in 272 parts 8 per cent nitric acid. Its specific gravity at 21° Temp. = 4.2741.

The silicic fluoride of magnesium prepared from humite, chondrodite (Plate I, Fig. 10), talc, biotite (Plate II, Fig. 6), rubellan, hypersthene, bronzite (Plate II, Fig. 9), and several other minerals,[1] appears in rhombohedrons whose vertical angles are usually truncated through the basal surface, or in combinations of R. ∞P2, R. ∞P2. 0R and other rather complicated rhombohedral forms.

All its crystal forms have sharp edges and smooth faces.

Upon two little crystals (of the microscopic preparation) having the combination R. 0R, which were found in an almost vertical position and remained dark between the crossed herapatites, I was able to measure the angles of horizontal projection. I found angles from 119° to 121°, therefore about 120°. In other positions between the crossed herapatites the crystals appeared colored red, yellow and blue.

Quite often the silicicfluoride of magnesium appears in rhombohedrons distorted on one edge, also in conical, cruciform, feathery and other imitative forms which sometimes have in the entire preparation the same regular arrangement, and every projection of which tends to terminate in an imperfectly formed rhombohedron.

The silicicfluoride of magnesium is quite easily soluble in water.

The silicicfluoride of iron ($FeSiF_6$ [$+6H_2O$?]) prepared by dissolving iron in hydrofluosilicic acid and evaporating the solution (in an iron crucible) in the air, usually crystallizes in pale bluish-green regular six-sided prisms (∞P2) which terminate in a rhombohedron.[2] Prepared in the form of a microscopic preparation (Plate I, Fig. 15) from the salt obtained from Herr Stolba and from siderite, it shows many individual and combined forms, also distorted forms of the hemihedral hexagonal system which appear colorless and can hardly be distinguished from the crystals and imitative forms of the silicic fluoride of magnesium.

1. Bastite, pennite (Plate I, Fig. 11), cordierite (Plate II, Fig. 10), olivine (Plate II, Fig. 11 and Fig. 12), brucite, mesitine, magnesite (Plate I, Fig. 12).

2. *Berzelius. Gmelin's handbook of inorganic chem*, 1875, *B*. 3, *p*. 403. On the appearance of the silicicfluoride of iron, see *Stolba. Sitzb. d. math. naturw. Cl. d. k. böhm. Ges. d. w. v. 27 oktbr*. 1876.

It is easily soluble in water.[1]

The silicicfluoride of manganese ($MnSiF_6+6H_2O$) appears according to Marignac (*Ann. Chem. ph.* [3], LX, 301, *u. Jahresber. ü. Fortschr. d. Chemie* 1861 [*pro.* 1860] *p.* 98) in pale reddish white crystals of the hemihedral hexagonal system, in the combination form ∞P2.R. According to the same investigator R : R=128° 20′.

Prepared in the form of a microscopic preparation (from the salt obtained from Herr Stolba and from dialogite, through the treatment of the latter with hydrofluosilicic acid) it appears in the same forms as the silicicfluoride of iron and the silicicfluoride of magnesium so that a separation of the three silicicfluorides according to type forms would hardly be successful.

Separation of the Silicicfluoride forms of Calcium and Strontium by means of Sulphuric acid (and more particularly as a test for the presence of Calcium).

If these silicicfluorides are treated with concentrated chemically pure sulphuric acid which has been diluted with an equal volume of water the crystals of the silicicfluoride of calcium are, after a few seconds, surrounded by a thick beard of colorless monoclinic needles, (gypsum crystals), while upon the crystals of strontium only a very slow solution into little grains (among which, a very few, extremely small, short needles [celestine?] are seen in some places) is to be noticed.

After some hours the preparation containing the silicicfluoride of calcium presents an aggregated mass of striated, very long, monoclinic needles and prisms, while in the preparation containing silicicfluoride of strontium nothing new is to be noticed except a few shapeless crystals.

I perform this experiment in the following way: Upon a watch crystal by means of a very finely drawn out tube, I place a few drops of concentrated chemically pure sulphuric acid; upon a second watch glass an equal number of drops of water of the same size as the drops of acid. Now I put a few drops of the mixture of the two substances upon the silicicfluoride, formed from the specimen, and place the cover-glass upon it and bring the preparation upon the table of the microscope. At this point one must move it very carefully, that the table of

1. Silicicfluoride of iron ($Fe_2Si_3F_{18}$) prepared by dissolving ferric hydrate in hydrofluosilicic acid and evaporating the solution, forms a yellowish jelly and after complete drying a half-transparent blood-red gumlike mass, which dissolves easily in water. (*Gmelin's Handb. d. anorg. Ch.*, 1875, *p.* 403.)

the microscope may not be soiled. Later on it will be noticed that the balsam plate is colored red (blood red) by the sulphuric acid; but since it does not lose its transparency this is no hindrance to the success of the experiment.

It might be noticed here that hexagonal prisms of pure silicicfluoride of sodium had, after one and one-half hours in sulphuric acid diluted with an equal volume of water, undergone no change except that they had assumed a slight reddish color. If on the contrary—prepared openly under other conditions which will be explained hereafter—they contained calcium, they dissolved, the more rapidly the more calcium they contained. Monoclinic gypsum needles shot up and increased quite rapidly upon the sides of the hexagonal prisms. The silicicfluoride of calcium, now changed into a sulphuric acid solution, separated again gradually into short hexagonal prisms, whose mass was greatest about the third day after the experiment; but about the fifth day after the experiment these crystals of silicicfluoride of sodium formed by crystallization in the sulphuric acid (diluted with an equal volume of water) had entirely vanished.

Separation of the Silicicfluorides of Magnesium, Iron and Manganese.

a. By the action of chlorine gas.

Place the object-glass upon which are the silicicfluorides of magnesium, iron and manganese, on a low frame (for example upon an inverted porcelain crucible) contained in the chlorine gas apparatus (which will be represented and described later) and heat the apparatus gradually so that small but numerous bubbles may be developed from the manganese muriatic acid solution. After the development of gas has continued from one and one-half to two minutes, the preliminary experiment may be considered complete.

Take out the object-glass, dry it carefully and place it upon the table of the microscope. In order, however, to protect the object-glass in all possible cases against accident, the silicicfluoride treated with chlorine gas may be furnished with a cover glass.

Upon observing all these silicicfluorides under the microscope, one finds that the silicicfluoride of iron has taken an intense citron-yellow color, without having lost much of the sharpness of its crystal forms. The silicicfluorides of magnesium and manganese on the other hand, have remained almost

colorless. The first shows a streak of grey, the second of red, and while the silicicfluoride of manganese has suffered a transformation into little crystals, melted prisms, tablets and grains, or seems entirely dissolved, the crystals of silicicfluoride of magnesium have only melted a little at the corners, so that they remain almost unchanged.

b. By means of ammonium-sulphide gas.

In a beaker place an inverted porcelain crucible, upon which lay the object-glass on which are the three silicicfluorides. Pour into the beaker a little pure sulphide of ammonium and cover with a glass plate; or yet simpler, hold the silicicfluorides over the opening of a flask filled with pure sulphide of ammonium.

In both experiments it will be noticed that the silicicfluoride of iron changes quite rapidly to blackish-gray with a peculiar metallic bronze lustre; while the silicicfluoride of manganese appears reddish or brownish-white and the silicicfluoride of magnesium grayish-white. Under the microscope the crystals of silicicfluoride of iron are quite black, in the thinnest places blackish-yellow; those of magnesium grayish-white, and those of manganse a peculiar reddish-gray, the last being sometimes changed into a granular mass. Near the forms of the two last named silicicfluorides, newly formed crystals of silicicfluoride of ammonium were noticed.

Completion of the preparation for the purpose of its preservation.

If it is desirable to preserve the preparation carrying the crystallized silicicfluorides as a proof of the result of the experiment, a cover glass must be fastened upon it.

If the investigated object is a thin section whose surface acted upon by hydrofluosilicic acid show distinct etchings it is better to cover it not with Canada balsam but with a thin layer of air, which can be managed by laying the cover glass directly upon it and cementing in at the margins with Canada balsam, made viscous by previous warming.

If the specimen is a thin section, upon which no peculiar etchings are observable, it can be covered with Canada balsam in the usual way and furnished with a cover glass. Yet the following method is advisable: lest the silicicfluoride crystals may be misplaced by the application of the Canada balsam and the pressure of the cover-glass, viz: use a rather weak solution of balsam—as one part Canada balsam and two parts chloroform

—lay the cover-glass carefully upon it and press it slowly and softly.

If the object is a grain of mineral, which was not wholly dissolved in the drop of hydrofluosilicic acid, remove the remnant with clean pincers if it would prevent by its projection the application of the cover-glass, and complete the preparation in the usual manner.

Remarks upon the Investigation of some of the petrologically important mineral groups according to the foregoing method.

a. Investigation of the Feldspar group.

Among the branches of the feldspar group, orthoclase (sanidine), microcline and albite (pericline), in the form of cleavage sections, are least affected by hydrofluosilicic acid; they, therefore, usually require a repeated treatment with this acid. or better still a treatment with fluohydric gas, which will be discussed later.

But if these same minerals in the form of thin sections are treated with strong hydrofluosilicic acid, the first attempt to gain knowledge of their chemical nature is apt to be sufficient. Orthoclase and microcline (Plate I, Fig. 16) which can easily be distinguished from each other by their internal structure, offer, on treatment with hydrofluosilicic acid tesseral crystals ($\infty 0 \infty$. 0, $\infty 0$. $\infty 0 \infty$) of silicicfluoride of potassium, and near them are often found very many tiny hexagonal prisms and tablets of silicicfluoride of sodium. Albite and pericline furnish only silicicfluoride of sodium (observed when magnified to the 400th power). Oligoclase poor in calcium, treated with hydrofluosilicic acid, gives (magnified to the 400th power) the same crystals as albite and pericline, extremely small but usually numerous hexagonal tablets (and very short prisms), which sometimes crowded closely together resemble very tiny spherical forms; but near them scattered individual spindle-shaped or other crystals of silicicfluoride of calcium are usually noticed.

Oligoclase rich in calcium furnishes with similar treatment distinct hexagonal prisms and numerous spindle-shaped forms of silicicfluoride of calcium. (In regard to the latter, however, it must not be overlooked that it is often necessary to adjust the microscope very carefully till the field of vision becomes dark, when the thin section specimen is most plainly visible).

In thin sections of andesine, which have been treated with hydrofluosilicic acid, beautiful hexagonal prisms of silicicfluoride of sodium are found, besides characteristically developed forms of siliicicfluoride of calcium.

In the varieties of andesine richest in lime the forms of both silicicfluorides appear to preserve, tolerably well, their quantitative relations, while in labradorite the silicicfluoride forms of calcium are in excess. And calcium appears in just so much greater degree in anorthite as it contains less of sodium. It will not be superfluous to remark here that the smaller the quantity of sodium present which is successful in development, the more easily the feldspar specimen is decomposed by hydrofluosilicic acid.

In order to be able to determine the individual members of the feldspar family as exactly as possible let a comprehensive series of the most important of these members—for which exact chemical analyses have been made—be prepared, which will give a clear view of the various quantitative proportions of the silicicfluoride forms of calcium and sodium in feldspars, obtained by the action of hydrofluosilicic acid; and let this series of preparations be used for comparison with every new specimen. Then will one be in a position to judge with which preparation the specimen under investigation coincides most perfectly and so to which feldspar branch it stands most nearly related. Moreover the feldspar specimens represented upon Plate I, Figs. 17–20, afford some interesting points.

b. Distinction of apatite from nepheline.

For the distinction of these two very similar minerals Streng has given us[1] perfectly satisfactory methods in thin sections, founded upon the application of molybdate of ammonium mixed with nitric acid and of concentrated muriatic acid as reagents. Hydrofluosilicic acid also gives satisfactory results.

The cross sections of nepheline become darker than those of apatite through the separation of the silica and the presence of numerous crystals of silicicfluoride of sodium, sometimes also silicicfluoride of potassium, while around the apatite may be noticed clusters and groups of striated long prisms and needles of silicicfluoride of calcium with the characteristic etchings. (Plate II, Fig. 16.)

c. Distinction of the minerals: enstatite, bronzite, hypersthene and diallage.

1. Tschermak's Mineralog. Mittheilungen, 1876.

All these minerals are characterized in their thin sections by a common feature, a parallel, sharply rectilinear, very close grooving and a slight dichroism, and may therefore give cause for confounding them; but treated with hydrofluosilicic acid they can easily be distinguished by the silicicfluoride crystals of the newly formed products.

Upon diallage the silicicfluoride of calcium and also those of magnesium and iron appear numerously. In the other minerals only the silicicfluorides of magnesium and iron are to be noticed. And if these are treated with chlorine gas or with sulphide of ammonium gas the quantitative proportions of the silicicfluorides of magnesium and iron can be estimated, so that one can judge which of the three minerals he has before him.

d. Distinction of amphibole and biotite in thin sections.

Although amphibole and biotite at first sight can be easily distinguished from each other it is not always the case in thin sections. For the thin sections of both minerals have often similar outlines and are usually marked by the same color and by parallel, rectilinear grooving, and always by strong dichroism. But after treatment with hydrofluosilicic acid silicicfluorides of magnesium, iron and calcium appear upon the amphibole thin section, and silicicfluorides of magnesium, iron and potassium upon the thin section of biotite.

e. Distinction of lithia-mica, lithia-iron-mica and ordinary potassium-mica or muscovite.

These three varieties of mica can scarcely be distinguished by crystallographic or by optical properties.

If, however, they are treated with hydrofluosilicic acid, there appear upon the surface of the lithia-mica (for example from Roznau, in Moravia) very tiny, six-sided pyramids of silicicfluoride of lithium, sometimes distorted by an abnormal development of two planes, which in the second variety of mica (for example, lithia-iron-mica from Zinnwald) are accompanied by crystals of silicicfluoride of iron. Upon muscovite (for example an ordinary potassium-mica from Greenland) only solitary hexahedral crystals of silicicfluoride of potassium can be noticed. Especially do these varieties of mica belong to those minerals which are acted upon with the greatest difficulty by hydrofluosilicic acid.

II. Application of Fluohydric Gas for the Identification of Alkali Metals in Silicates, Especially in Those Which are Only Slighthy Affected by Hydrofluosilicic Acid.

Principle of the Method.

If a silicate is treated with fluohydric gas, its metals will be changed into silicic fluorides, single or double fluorides, of which one can easily become convinced by observing the fermentation[1] when the specimen is further treated with concentrated sulphuric acid.

By the action of hydrofluoric gas upon alkaline silicates silicic fluorides of the alkalies are formed, which, extracted with boiling water, can be brought to crystallization by evaporating the solution to one drop and placing this upon the object-glass, and can then be observed under the microscope. These forms are not essentially different from those produced by hydrofluosilicic acid.

In this way the most positive determination can be made for the smallest quantity of alkali in silicates, especially of potassium.

If the specimen treated with fluohydric gas and afterward boiled down in water contained alkaline earths besides the alkalies, usually only a small portion of the alkaline earths is dissolved, in the form of silicic fluorides in the aqueous solution, the larger portion remaining in the specimen.

Several experiments which I made upon feldspar specimens for the purpose of separating all the alkalies of that part of the specimen changed by the fluohydric gas as silicic fluorides and retaining in the specimen the greater portion of the calcareous earths as a fluoride, led approximately to this rule: That the specimen (of 2—6 □ ^{mm} D.) treated with fluohydric gas should be boiled upon a platinum dish (of 45 ^{mm} D,) filled with water, as many minutes as the upper surface of the specimen contains □ mm. And the calcium fluoride remaining in the specimen can then be dissolved in concentrated sulphuric acid and made visible in the form of gypsum crystals so that its quantitative relation to the alkalies can be estimated.

But if the specimen treated with fluohydric gas contains only alkalies (and no alkaline earths) then, after a complete removal of the silicic fluorides of the alkalies (by boiling away

1 As a result of the development of hydrofluoric gas and silicic fluoride at the same time.

in water), on further treatment of the specimen with sulphuric acid no fermentation and especially no devlopement of fluohydric gas is observed.

Before I was certain of the application of hydrofluo silicic acid, as the most suitable reagent for the determination of individual metals in minerals, I used fluohydric gas and sulphuric acid for the detection of single members of the feldspar family and in the following manner:

After I had taken all the silicic fluorides from that portion of the specimen changed by fluohydric gas by means of boiling with water, I allowed these silicic fluorides to crystallize upon an object glass. I then decomposed the calcium fluoride remaining in the specimen by means of sulphuric acid, and allowed the calcium sulphate to make its appearance on a second object glass in the form of gypsum crystals. By comparing the quantitative proportions of the crystals of silicic fluoride and the gypsum crystals I was able to draw a corresponding conclusion regarding the quantitative relations of the alkali metal (sodium) to calcium.

Moreover, I sometimes tried the following plan: I treated two specimens of an equal size, and equally changed by fluohydric gas, with equal drops of sulphuric acid, one piece after the other, after the boiling with water, and noted in each case (*a*) the continuance of effervescence, or development of gas, and (*b*) the quantity of gas bubbles developed, enclosed by sulphuric acid.

From the relations of the data preserved, I was able to draw a correct conclusion regarding the quantitative proportions of sodium to calcium in oligoclase feldspar; for by treatment of the specimen, changed by fluohydric gas, with sulphuric acid before boiling away with water, all the fluorides were decomposed, while by treatment after boiling away with water, only the undissolved calcium fluoride remained for separation.

Experiments made upon a specimen of chiastolite with fluohydric gas, showed through the effervescence of the specimen in sulphuric acid that the clay was also changed into a fluoride, which was dissolved in water but not crystallized.

EXECUTION OF THE METHOD.

Apparatus for the development of fluohydric gas and for the reception of the specimen.

In order to develop the fluohydric gas and cause it always to act upon the thin section or specimen of whatever kind,

I use a platinum crucible of the size of Fig. 1. In the crucible is a frame of platinum wire which supports a platinum plate pierced with an annular opening, with upturned edges; the margin of the plate and one circular opening in the center also have upturned edges. This plate serves for the reception of the specimen.

Fig. 1 represents a section of the crucible with the frame and plate, and Fig. 2 the surface of the plate.

Fig. 1.

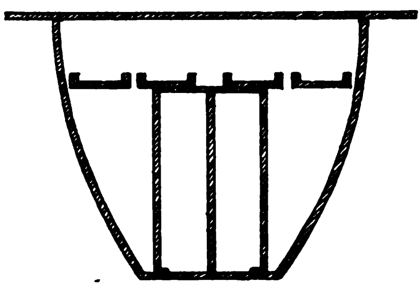
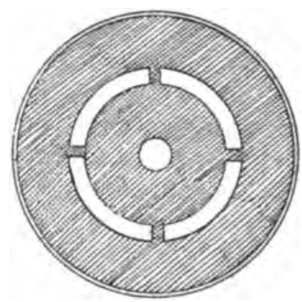


Fig. 2.



Instead of the plate a narrow strip of platinum may be used to receive the specimen.

For covering the crucible I use a circular piece of platinum which extends over the edge of the crucible, and is furnished, upon that side which is next the crucible, with a coating of wax (to be warmed before each experiment), in order to make it adhere firmly to the crucible. To assist in this, a weight is laid upon the piece of platinum acting as cover.

The thin sections or pieces to be investigated are so placed upon the platinum plate (or strip of platinum,) that little spaces are left between them so that a greater or less number (from 10 to 20) of specimens, according to their size, can be exposed at once to the action of fluohydric gas.

Only, at this point, it is necessary to note the relative positions of the specimens in order to avoid errors in subsequently confusing them.

Treatment of the specimen with fluohydric gas.

On the floor of the platinum crucible, scatter a half gram of pure finely powdered fluoride of barium,[1] place the platinum frame in position and pour upon the inner surface of the crucible enough concentrated chemically pure sulphuric acid to entirely cover the fluoride of barium; then sieze quickly (because the

1. Mercantile fluoride of barium needs to be mixed with barium chloride or sulphate of baryta.

escape of fluohydric gas has already begun) with a pair of pincers the turned up edge of the platinum plate carrying the specimens, lay this upon the frame of platinum wire, cover the crucible with the above mentioned waxed platinum cover and place a weight upon it in order to hold the platinum cover firmly over all.

The entire apparatus covered with a glass tumbler or an inverted beaker may now be left standing in any convenient place.

If a strip of platinum has been used for holding the specimens instead of the platinum plate, sufficient space must be left next the strip for the sulphuric acid to be poured in after the introduction of the specimens into the crucible, in which case it is necessary to close the crucible as quickly as possible to prevent the escape of the fluohydric gas into the air.

In order to allow the fluohydric gas to act upon the specimen as long as possible I am accustomed to leave the apparatus closed until the second day, when it is opened in a draught cupboard.

After the settling of the fluosilicium and the removal of the superfluous fluohydric gas, the platinum plate with specimen is taken out and the specimens closely examined to see if any of them are spotted by the effervescence of the fluoride of barium or by the sulphuric acid.

Boiling away in chemically pure water of the specimen changed by the action of hydrofluoric acid. Extraction and crystallization of the silicic fluorides of the alkalies. Their appearance under the microscope.

Cut from the thin section acted upon by hydrofluoric gas a specimen of 3—6 □ mm, or if the specimen acted upon was a fragment, cut a piece of the size of a small pea and lay it in a perfectly clean platinum dish, fill the latter with chemically pure water, take it up with iron tongs and hold it in the flame of a spirit lamp until the water has boiled at least as many minutes as the surface of the specimen contains □ mm. By gentle movements of the vessel take care that the specimen moves about in the water.

After the boiling remove the specimen from the water with perfectly clean pincers, wash it with water and lay it one side upon an unused object glass.

Evaporate the aqueous solution at not too high a temperature to one large drop, place this upon the thin (hard) balsam surface of an object glass and let it dry in a place free from dust.

During the drying the silicic fluorides separate in beautifully formed crystals which, after complete drying, can be examined with the microscope (most successfully when magnified to the 400th power.)

The silicic fluoride of potassium appears in hexahedrons, which, at times, form splendid cruciform or chandelier-like groups, or in combination forms of the hexahedron with the octahedron, or of rhombic dodecahedron with the hexahedron. Often these are imperfectly formed crystals of the tesseral system, distorted in the line of the axes; but their opacity between the crossed Nichols seems to easily distinguish them from the silicic fluorides of all other metals, (unless it be the similarly formed silcic fluorides of metals that occur very infrequently: cæsium, rubidium, thallium.)

The silicic fluoride of sodium appears in hexagonal prisms which are terminated by basal planes, or by a blunt pyramid, whose vertical edges are sometimes blunted by the narrow planes of a secondary prism. Yet quite often regularly formed crystals of silicic fluoride of sodium, barrel-shaped, oval, elliptical and cylindrical forms, which belong to the same silicic fluoride metal, are found near these.

From all the specimens of oligoclase feldspar, I obtained near the above mentioned forms of sodium, a small quantity of long pointed needles, or long thin four sided prisms terminated by a couple of inclined planes, which I think I may regard as silicic fluoride forms of calcium, since the above mentioned feldspar contains, besides sodium, calcium and aluminium, no other constant metal, and since from pure clay silicates (chiastolite and kaolin) no silicic fluoride appeared in such needles and prisms, yet I always found these forms in small quantities in anorthite and wollastonite.

The silicic fluoride of sodium, prepared from the specimen of oligoclase feldspar, appeared commonly in imperfectly formed, barrel-shaped, oval and cylindrical crystals, which sometimes, having pierced through the striated mass of needles and prisms of silicic fluoride of calcium, presented splendid groups.

Treatment of the specimen boiled in water with sulphuric acid

Near the specimen, freed from silicic fluorides by boiling in water, and which has been laid upon an object-glass, place one or two drops of sulphuric acid and lay over it such a cover-glass that the specimen will be covered with tne acid. Now observe

(eventually also in the microscope) whether gas comes off or not. If no gas is formed then heat the object-glass gently some ten or fifteen seconds, touching the point of the flame of the spirit lamp with the edge of the object-glass.

If no gas is developed in the last named case, there are no metallic fluorides existing in the specimen boiled with water.

If, for example, the specimen was a member of the feldspar family, and if the aqueous solution has shown only silicic fluorides of the alkaline metals, then one may be certain that the specimen is a pure potassium or natron feldspar (orthoclase sanidine or microcline, or albite, or pericline, according as the silicic fluoride crystals obtained belong to potassium or sodium). If only a very weak gas development is noticed in the feldspar specimen boiled with water, and the specimen is very thinly covered with gas bubbles, or surrounded by a thin, spongy bubble-wreath, then one may assume that he has examined a member of the oligoclase series. But if a strong and continuous development of gas and of gas bubbles occurred, then one has,—according to the quantity of silicic fluoride crystals of sodium obtained from the specimen—a member of the andesine or labradorite series. Anorthite may in most cases be recognized by treating the feldspar specimen before boiling with water, since it shows no effervescence, but only a slow but strong development of tolerably large bubbles of gas is noticed, while all oligoclase feldspars treated with hydrofluoric gas effervesce in sulphuric acid, the more energetically the more soda they contain.

In order to estimate correctly the proportion of sodium which has been obtained in the form of silicic fluoride crystals, to the calcium fluoride remaining in the specimen, pour off the drop of sulphuric acid with the rest of the specimen from the object glass, into a clean platinum dish, remove the specimen and evaporate the sulphuric acid by heating the platinum cover. Dissolve the residuum which may be left in a large drop of water, place it upon a clean object glass and allow it to dry. From the quantity of gypsum crystals formed, which can now be examined upon the object glass, by aid of the microscope, in proportion to the quantity of silicic fluoride crystals of sodium, which one has obtained from the aqueous solution, a safe conclusion can be arrived at as to which series the feldspar specimen belongs to.

Remarks on the application of hydrofluoric gas for purifying turbid thin sections, bringing forth clearly the mineral outlines as well as the mineral structure, and on the identification of colorless inclusions in colorless minerals.

It frequently happens that thin sections of rocks which have attained the greatest possible thinness are still unfit for microscopic investigation by the presence of several dark mixed substances disseminated through the entire mass. In such cases the petrologist must next solve the problem of how to remove the dark substances without crumbling the section.

In my earlier work I used hydrochloric acid for this purpose. I fastened the turbid thin section to an object-glass by means of Canada balsam, and let it lie in a little cup containing hydrochloric acid several hours or days, according to the acid's action on the thin section. But since the balsam plate under the thin section became dimmed and opaque by the hydrochloric acid, I put upon the other cleaned and dried half of the object-glass some new balsam, to which I gave by heating the necessary consistency, and shoved over upon it by careful warming, the easily freed thin section. I could now cover it with a new balsam layer and apply a cover-glass, as is customary in preparing a thin section for investigation.

In this way I obtained satisfactory results. Thus, for example, I succeeded in removing the calcite from the dark thin sections (quite unfit for microscopic study) of grayish white calcareous aphanite (diabase amygdaloid) from Krusná Hora, near Beraum, and then with the thin section, now quite transparent as well as perforated, in proving that the original substance of the calcareous aphanite is identical with the greenish black heavy diabase of the same locality.

Fluohydric gas also renders similar service, if the thin section is either first boiled with water or treated with sulphuric acid according to its mineral properties. Thus the thin sections of a compact porphyry, quite opaque but thin as paper, on treatment with fluohydric gas and subsequent boiling with water, became quite clear and bright and the fragile feldspathic forms scattered through the close quartz grains were readily recognized; moreover sections of nepheline phonolite, dark but thin as paper, required besides treatment with fluohydric gas and water, sulphuric acid in order to become perfectly clear and transparent.

An interesting appearance presented itself to me in a thin section of phonolite from the Wachholder Mts. at Teplitz, where

the ground mass consisting of a homogeneous polarizing substance (without recognizable outline) is, after successive treatments with hydrofluoric gas, sulphuric acid and water, resolved into rectangles and hexagons of nepheline. And upon this section of nephline appeared a significant scaly structure of which nothing was before noticed. It is evident that Möhl's nepheline-glass was represented here in plain sections.

Before Des Cloizeaux's epoch-making works, "Mémoire sur l'existence, les propriétés optiques et cristallographiques, et la composition chemique du microcline etc." (Extrait des Compt. rendus, etc. t. LXXXII, 17. Avril 1876; and Extrait des Ann. de chimie et de Phys., 5th séries, t. IX., 1876) were by the kindness of the distinguished author placed in my hands, I had already observed the characteristic microstructure of amazonite from Miask, and of microline from Karlsbad[1] (from the systematic collection or the Bohemian museum, with the label "orthoclase [white, transparent laminated] from Karlsbad"), and upon the ground of the changes effected by hydrofluoric gas and water, I judged that internally or structurally different laminæ are present; but I also found in many oligoclase feldspars laminæ which under the influence of the above named reagents showed a substantial difference.

III. Application of Chlorine Gas for determining the Insolubility of Minerals in Acids, the Gelatinous Nature of Silicic Earths separated from the thin sections of many Silicates, and for the Determination of Alkalies, Alkaline Earths and Iron-Protoxide.

Development of Chlorine Gas, and treatment of the specimen with it.

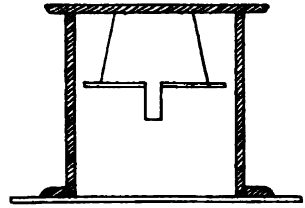


Fig. 3.

For developing chlorine gas I use a glass vessel (somewhat of the form represented in Fig. 3), upon the bottom of which is evenly scattered finely powdered manganese in the form of a ring an inch in width, and moistened with muriatic acid. Two strips of glass will serve to hold the mineral and thin-section specimens. These strips should be cemented to the upper side of a glass stopper on either side of

1. The microstructure of the Karlsbad microcline corresponds quite well with that which Des Cloiseaux in his above named works (p. 8, fig. 12) describes as a microcline from Australia (?).

the handle (as illustrated in Fig. 3), and by means of the stopper lowered into the middle of the glass vessel from whence they can be easily withdrawn when the operation is completed.

But if microscopic silicicfluoride crystals which are upon an object-glass, are to be exposed to the action of chlorine gas, then a low uncovered porcelain crucible may be used to support the object-glass.

When the frame carrying the specimens has been placed in the glass vessel and the latter closed as tightly as possible with a glass plate, whose edge has been rubbed with grease, then place the glass vessel upon a wire netting over a spirit-lamp and heat it till gas has developed rapidly for five minutes.

Special care must be taken while heating this that no large bubbles form lest by their bursting, the specimen should be soiled.

After about five minutes development of gas, the vessel should be taken from the flame and, with its cover, left standing twenty-four hours upon the work-table; but during this time the heating (for the development of a new portion of chlorine gas) may be repeated, as often as the nature of the mineral under investigation may require.

After the action of the chlorine gas has lasted about twenty-four hours, the frame, (the glass stopper) with the specimens, is taken out, each specimen laid upon another object-glass (with the side acted upon uppermost) and subjected to microscopic examination.

If the presence of (liquid) chlorides of the alkaline earths (calcium and magnesium) as new formations, is expected and it is wished to obtain them in characteristic crystalline forms, it is advisable to place the object-glass holding the specimen in a drying dish for the complete drying of the specimen, then to immediately enclose it in Canada balsam and place it under a cover glass.

If microscopic silicic fluoride crystals (upon an object-glass) are exposed to the action of chlorine gas, from three to five minutes of this action is sufficient to bring out the characteristic changes upon the silicic fluoride crystals; then the object glass is to be taken out, thoroughly cleansed and the changed crystals examined under the microscope.

Proof of the insolubility of a mineral in acids.

For testing the insolubility of certain minerals of a mixed rock in acids, the specimen in the form of powder was usually

boiled in hydro- chloric acid, shaken and left standing for some time. Then the changed specimen was investigated by microscopic observation and compared with fresh material for the purpose of establishing which minerals were wholly decomposed, which in part and which remained undecomposed.

Although the recognition of half-decomposed minerals in their tiny fragments under the microscope was often attended with difficulty, still these methods led in many cases to the desired result, provided the strength of the acid, the continuance of its action and the temperature by which the action was accompanied received proper consideration in proportion to the effect obtained upon determined minerals of the specimen.

Especially important was the fulfillment of these conditions, if the specimen was treated in the form of a thin section, since in this case a complete decomposition of the mineral had not been sought but only a clear change upon its (the thin section's) upper surface (evident mainly along the edge and in the clefts).

In the investigation of the insolubility of minerals in acids when occurring in crystalline rocks, it was found profitable to lay the thin section fastened to the object glass by Canada balsam in a little cup having a smooth bottom, in which has been placed, according to thc requirements, hydrochloric acid or aqua regia; to leave it in this several days in perfect quiet, and then, after removing the acid from the specimen by careful immersion in chemically pure water, (the object glass being in a horizontal position) and drying with great care, to subject it to microscopic examination; for by this process it was possible not only to observe the decomposition of many minerals by means of the changes on their upper surfaces, but also to determine the nature and quantity of the silica separated from the silicates.

If the lower part of the specimen on the balsam plate has become, by the action of the acid, dark and opaque it can by careful heating be loosened and slipped upon a new balsam plate placed upon the same object glass.

Instead of all these methods for determining the insolubility of the several minerals in a thin section, I believe a new one may be presented as the most useful, namely, that which is based upon the action of chlorine gas upon thin sections of rocks and minerals.

According to this method the thin section specimens are laid upon the glass strips of the frame (glass stopper) in fig. 3, page 36, as close to the edge as possible but not so close to-

gether as to touch and in the manner described above (pages 36 and 37) exposed for about twenty-four hours to the action of chlorine gas. After being taken out of the apparatus each specimen is placed upon a new object-glass (arranged with the treated surface uppermost) and examined in the microscope.

If the thin section is spotted upon its upper surface with drops of chlorine water—which usually occurs with minerals which separate much gelatinous silica—the specimen may be dried in the exsiccator.

With the microscopic investigation here proposed, for which previous experiments upon determined minerals must be laid down as a guide for the determination of the decomposition of a thin section of mineral by means of chlorine gas (under the above mentioned conditions) the following points must be observed: (*a*) the nature and quantity of the silica separated out of the silicates, (*b*) the quantity of the chlorides formed upon the upper surface of the mineral, (*c*) the nature and strength of the etchings effected by the chlorine gas.

The following may be taken as a general rule: *The more the silica that has separated from a silicate, the more the chlorides that have formed and the more strongly marked the etchings, so much the greater is—under a like condition—the decomposition of the mineral.*

Determination of the gelatinous nature of the silica separated upon the upper surface of silicates.

If one has observed in the microscope the gelatinous silica separated by chlorine gas, upon the surface of some minerals, for example, nepheline, elaeolite or olivine, and has distinguished it from the powder-like silica of some minerals, he is in most cases able to determine whether the silica separated upon another mineral, is of a gelatinous or powder-like nature.

In order, however, to determine in every case with certainty the nature of the silica, the method proposed by Behrens, which is based upon the capacity of gelatinous substances for absorbing coloring matter, is strongly recommended.

I make use of this peculiarity of gelatinous substances in the following way: I cover the thin section treated with chlorine gas and placed upon a clean object-glass with a drop of fuchsin-solution, and after some time I lay the object-glass with the thin section upon it in a crucible filled with chemically pure water.

If there is no gelatinous substance upon the upper surface of the thin section, the color of the thin section vanishes in a

very short time, since the coloring matter mentioned is very easily soluble in water, but if there is gelatinous substance upon the upper surface of the thin section then every smallest part of the gelatined silica will be affected by the red fuchsin solution, which cannot be removed from gelatinous substances by water.

In this process, care should be taken that the thin sections be thoroughly cleansed before the treatment with the chlorine gas and that no portion of the silica be spilled from the surface of the thin section into the water by the movement of the object glass. While the latter condition is very easily fulfilled by a careful carrying out of the operation mentioned, the former usually requires a suitable cleansing of the thin section with alcohol or better still with chloroform, since the least trace of Canada balsam which remains imbedded in the crevices of the thin section may produce the same result as gelatinous silica.

This method is excellent *for distinguishing nepheline from apatite* and from monoclinic feldspar forms, and equally so for *distinguishing hauyne* and *nosean from leucite.*

The application of this process upon the thin sections of various kinds of rocks, especially upon the thin sections of basalt from Schlanberg and of nepheline phonolite from the Wachholder mountains at Teplitz is very satisfactory. The thin sections of the first rock, magnified to the four hundredth power, showed intense red olivine, nepheline and hauyne flakes in regular arrangement between augite groups, and numerous, colorless apatite sections, while on the phonolite thin section, the quantity of sanidine tablets remaining colorless between the red nepheline sections could be easily examined and determined.

Preparation and examination of the chlorides formed by the action of chlorine gas.

By the action of chlorine gas upon a silicate which contains alkalies and alkaline earths, and which suffer decomposition by means of the above mentioned reagent, metals of the alkalies or alkaline earths are, in the changed portions of the silicate, produced in the form of chlorides which appear upon the surface of the fragment of thin section in more or less perfect crystals.

The chloride of sodium very readily crystallizes. Its cube shaped crystals and step-like structures are best seen in those silicates which separate powder-like silica (as for example, andesine, labradorite), but far more numerous do they appear upon those silicates containing soda (as elæolite), but they lie

imbeded in the silicic gelatine and are more or less covered with it.

In order to determine the sodium chloride crystals in the last named case, it is advisable to cover the specimen with a solution of Canada balsam in chloroform and to supply it with a cover-glass; for in this way the silicic gelatine becomes strongly pellucid and shows the colorless cubes of sodium chloride. The chloroform, moreover, seems to cause the sodium chloride left in solution in the gelatinous silica to crystallize.

Less easily does the chloride of potassium, which is isomorphous with sodium chloride, crystallize. And, to cause the rhombohedral prisms (∞ R. R.—R. 0R) and tablets of calcium chloride ($Ca\,Cl_2 + 6H_2\,O$), and chloride of magnesium ($Mg\,Cl_2 + 6H_2\,O$), which liquify on exposure to air, to crystallize upon mineral thin sections by treatment with chlorine gas, is most difficult of all.

The forms of the two last named substances, which usually present distinct crystals only under the exsiccator, are generally spherical, elliptical or cylindrical, if they are successful in formation.

From the ferruginous silicates, which suffer decomposition on treatment with chlorine gas, appear often chlorides of iron. But since they belong to substances most soluble on exposure to air, they will not appear clearly in crystal forms upon the mineral thin section, but appear as a half-liquid pigment upon the mineral from which they are derived, gradually impregnating the adjoining portions of the thin section. Thus, from ferrous chloride as well as ferric chloride may proceed the intense yellowish-green or greenish-yellow color which appears upon the colorless or pale yellow olivine section, or upon other minerals containing iron protoxides, if they are exposed to the action of chlorine gas.

Judicious use of Streng's methods for the identification of apatite in thin sections, and especially after treatment with chlorine gas.

In order to determine apatite in thin sections of rock, [1]Streng has made the practical suggestion that the thin section, placed upon an object-glass, be treated first with hydrochloric acid (to dissolve the apatite) and then with molybdate of ammonia (diluted with nitric acid until the white precipitate again dissolves), then furnished with a cover glass and studied under a microscope. From the quantity of tiny but shapely formed

1 Tschermak's Mineralog. Mittheilung. 1876.

citron-yellow crystals (magnified to the 400th power) which I have usually regarded as rhombic dodecahedrons, (rarely octahedrons) of the tesseral system, the quantity of phosphate (apatite) appearing in the thin section can usually be determined in similar proportions.

Since apatite, like every other phosphate, is more or less affected by chlorine gas, the thin section treated with chlorine gas, in which one has already microscopically studied the decomposition of the minerals, can, for the determination of the phosphoric acid, be treated with one or more drops of molybdate of ammonia[1] diluted with a corresponding amount of nitric acid, and furnished with a cover-glass for microscopic examination; eventually, also, inclosed in Canada balsam applied at the edge of the cover glass.

The result is in general the same as that shown in the first paragraph; but in particular it is to be observed that if silicates which have separated gelatinous silica exist near rich apatite in a thin section, they are just as much impregnated with the citron-yellow substance of the phospho-molybdate of ammonia compound, as with the red fuchsin solution. Thus the reaction under these conditions serves a double purpose: (*a*) the proof of the existence of a phosphate in the thin section, and (*b*) the proof of the gelatinous nature of the silica separated from a silicate.

IV. The Production and Observation of Etchings, and their Importance in the Determination of Minerals in thin Sections.

In the introduction (page 6), all those works were specified which treat of the representation of etchings upon various surfaces of many minerals and of their crystallographical significance. But at the same time the remark was made, that up to the present time no decided step had been taken to turn to account these etchings for determining the individual minerals in thin sections.

I am unfortunately unable to describe a large series of favorable results; for only upon the thin sections of a few minerals have I observed perfectly characteristic and, according to the above methods, easily presented etchings, which show finely the structure of the crystals of the individual minerals. But

1 The superfluous molybdate of ammonia crystallizes upon the object-glass in colorless needles.

the thin sections of most minerals treated with hydrofluo-silicic acid or hydrofluoric gas, or chlorine gas, show upon their upper surfaces changes produced by etchings, which, although hardly definable in words, present to the observer not an accidental appearance, but one closely connected with the inner structure of the mineral, so that in most cases their examination seems to be of value.

Since the nature of the etchings—by which term I believe it is allowable to indicate all depressions and protruberances in any degree characteristic, produced upon the mineral section by a chemical reagent—depends upon the crystallographical condition of the mineral section, various etchings naturally appear upon the various sections of the same mineral; and this furnishes us with a reaction which sometimes is not unimportant in the determination of a mineral.

It is to be noticed that with the appearance of the etchings on mineral sections new products also appear by the action of the chemical agents, or substances (like silica) are separated, which cover the etchings more or less wholly and must therefore be removed if the etchings are to be clearly studied.

If the new formed products are silicic fluorides or chlorides their removal from the surface of the thin section can be secured by repeated boiling in water, which can be conveniently done upon a platinum lid. And by the mechanical action of the boiling water the silica which may have separated is usually washed away from the surface of the thin section. If the new formed products are fluorides of alkaline earths which are insoluble in water they can be dissolved by sulphuric acid and then removed by water. But in the latter case it must be noticed that the action of the sulphuric acid upon the surfaces of many minerals results in additional etchings.

In order that the surface of an etched mineral section freed from new formed products and thoroughly cleansed may be conveniently observed under the microscope it should not be covered with Canada balsam but, if the section is to be preserved in the form of a microscopic preparation, a cover glass should be at once placed upon it, and the edge of this cemented to the object-glass by Canada balsam or some similar substance, the proper consistency being attained by heating on an object-glass.

1. *Etchings produced upon the surface of apatite.*[1]

1 Boricky. Sitzungsber, d. k. Böhnn. Ges. d. Wissemsch, V. 9 Feb., 1877.

a. By action of chlorine gas.

By the action for twenty-four hours of chlorine gas upon thin sections of apatite from Schlackenwald, the sections being cut parallel with the basal planes, their upper surface (magnified to the 400th power) was changed into an aggregate of apparently hexagonal crystals, thickly crowded together and clinging to each other (subindividual crystal molceules) (P or P. 0 P or 0 P. P) which were placed for the most part perpendicular to the basal planes or showed only a slight inclination toward them.

In the outer zones the crystals were of various sized diameters and distinguished for the most part by prominent basal planes, but the boundary lines of the outer zone were sharply defined by crystals closely crowded together, of almost an equal size and exactly parallel to the crystal outline, running out, for the most part, into pyramidal points, so that a more splendid illustration of inner crystal structure could hardly be expected from any other chemical agent. (See Plate II, Figs. 19 and 20.)

Above the crystals there sometimes lay a mixture of short needle-shaped forms whose horizontal projections toward each other, showed for the most part an inclination of 60° or 100° and which I thought could be considered the remaining edges of the vanishing crystals of the upper layer. And these crystal-needles appeared most clearly when the thin section was covered with Canada balsam and furnished with a cover glass.[1] (See Plate II, Fig. 18). On the other hand the crystals situated beneath (the subindividual crystal molecules) could hardly be perceived through the Canada balsam.

Upon the thin section of the same apatite, crystals cut almost parallel to the prism surface (∞ P) which were boiled for a few seconds in aqua-regia, there appeared plainly in some places rhomboidal lateral angles, showing for the most part a splendid scale structure, while the rest of the thin section showed regular rhombic figures or rhombic figures long drawn out, and laterally truncated, parallel and crowded together or closely behind each other, (see Plate II, Fig. 17.)

The etchings of the apatite thin section boiled several minutes in water in a platinum dish were not injured but the tiny crystals appeared still more beautiful and clear; only the tiny needles (probably edges remaining from the upper layer) were scarcely visible.

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1 Upon which bubbles of air were noticed almost continually.

Upon the natural surfaces of apatite—probably on account of greater insolubility—the abovenamed etchings were not noticed. There appeared upon the prism surfaces sharp grooves of varying lengths, and three cornered and trapezoidal forms. And upon a few places only were seen isolated rhomboidal angles (the lateral angles of tiny pyramids).

b. By action of hydrofluosilicic acid.

The etchings produced upon a thin section of apatite, cut parallel to the basal plane, by action of hydrofluosilicic acid, though only appearing plainly after the removal of the quantity of silicic fluoride of calcium formed. (removed by boiling in H_2O), showed (magnified to the 400th power), no material difference from the etchings which were described in the preceding paragraph, as being produced by chlorine gas. Yet in many places the peculiarity was to be noticed that the subindividual crystal forms of the principal basal surface with the pyramid, appeared composed of the regular crystal scales or of step-like crystals built up according to the hexagonal tablet as (0P. P) being always smaller above. Figure 16, plate II shows the silicic fluoride of calcium and the etchings produced upon the basal plane of an apatite crystal by the action of hydrofluosilicic acid.

2. Etchings upon a thin section of olivine, produced

a. By hydrofluosilicic acid.

The etchings produced by the action of hydrofluosilicic acid upon a thin section of olivine from Kozákov (at Turnau) and freed from the silicic fluorides of iron and magnesia by boiling with water (when magnified to the 400th power) are very regular crystal forms, closely crowded together and perfectly parallel to each other, of the pyramidal or tablet-shaped habitus, which latter, if they are not perfectly formed or not clearly visible, resemble rhombic figures overlying each other or clinging together.

By the individual crystals of pyramidal forms, a pinacoid or a dome may seem to be combined in the same zone with the predominant rhomboidal pyramid, while on the tablet-shaped crystals near the principal pinacoid a pyramid, prism or dome may appear not falling in the same zone with the pinacoid.

Magnified to the 400th power these subindividual crystals attain in some olivine sections the size of barleycorns; upon other sections they appear only like pinheads furnished with

two sharp and two blunt corners, and arranged regularly upon the entire section, (See Plate II, Figs. 11 and 12,) upon which the silicic fluorides are also shown near the etchings.

b. By the action of chlorine gas.

The etchings produced by chlorine gas upon thin sections of olivine from Kozákov are mostly short; not rectilinearly bounded, but usually perfectly parallel grooves, among which short pointed prisms or pointed rhombic figures were found in a very few places.

3. *Etchings upon thin sections of dichroite produced by action of hydro-fluosilicic acid.*

The etchings observed upon the thin sections of dichroite (from Bodenmais and from Orrijaerfvi in Finnland) were for the most part short rectangular depressions either parallel througout or one lying almost at right angles to another, between which were found more or less regularly laid grooves of various lengths. Only in a few places were the latter predominant; moreover among the regular some isolated depressions also appeared which showed much similarity to the crystal forms of dichroite represented in Naumann's Elements of Mineralogy (1871, p. 404). (See Plate II, Fig. 10, in which, for the most part irregular etchings are represented near the silicic fluorides).

4. *Etchings upon thin sections of chiastolite produced by the action of hydro-fluosilicic acid.*

In the thin sections of a chiastolite crystal (from an unknown locality) which were cut parallel to the basal planes, a charry substance appeared in more or less thickly packed particles, not only in the central part (along the crystallographical axes), upon the vertical lateral edges and along the diagonal of the thin section, but also in other parts of it and indeed in feather-like ramifications which ran out from the diagonal parallel to the edges of the oblique crystal section. The chiastolite substance appeared to be somewhat homogeneous, without showing anywhere a special micro structure except the imperfect cleavage crevices and a few small almost wholly colorless spots.

But after treatment with hydro-fluosilicic acid the imperfect cleavage crevices appeared like broad spotted veins which were traversed with very broad undulating fibrous border zones, and enclosed little irregular rhomboidal, colorless spaces, so that the most important part of the thin section was marked by a strong spotted or undulatingly-fibrous structure.

Upon several points on the edge of the thin section appeared instead of the spots, promiscuously arrainged groups of long slender bands which—just like the spots and fibers produced from the chiastolite substance—presented the idea of a paramorphosis.

The colorless, somewhat less distinct rhomboidal spaces which may be considered as the residue of the unchanged chiastolite substance were cut by rare but quite perfect cleavage crevices which crossed almost at a right angle (90° 31' and 91°) and corresponded almost exactly with the cleavage directions of chiastolite (91° 4'). (See plate II, Fig. 13).

5. *Etchings on thin sections or cleavage fragments of hypersthene, broncite, diallage, augite, and amphibole produced by hydrofluosilicic acid.*

While the sections of hypersthene from Sky Island and of broncite from Graubat in Steiermark, treated with hydrofluosilicic acid, presented a union of fragile parallel fibres or very slender bands (see Plate II, Fig. 9, broncite from Graubat treated with H_2 Si F_6) the thin sections of diallage from the gabbro from Wolpersdorf showed usually two systems (cutting each other at a sharp angle) of less close but sharply rectilinear cleavage crevices between which groove-like etchings, much twisted and intertwined, appeared closely crowded together (see Plate II, Fig. 8). And these thin sections of diallage enclosed little broncite particles whose microstructure seemed uniform with that of broncite from Graubat.

Upon the thin sections of augite[1] and amphibole[2] which were cut parallel to the pinacoid face, only grooves of various lengths were noticed, which followed almost uniformly a fixed direction.

6. *Etchings on Lithia-iron-mica from Zinnwald, produced by the action of hydrofluoric gas and subsequent boiling with water.*

After treatment with hydrofluoric gas and water, there appeared upon the pale yellow or reddish white scale of this mica irregularly distributed, rusty-yellow flakes which often showed rhomboidal or six-sided incoherent outlines. And upon many places free from the rusty yellow flakes appeared very slender, more or less thickly congregated (depressed), rhombic figures, which were arranged for the most part parallel to the rhombic edges. (See Plate II, Fig. 14).

1. From Wartha on the Eger and from Kaaden.
2. From Peperin basalts from Lukov at Milleschau (see Plate II, Fig. 7).

I have measured many of the acute and obtuse angles of these rhombic figures, but obtained very different results; for the acute angles 49° 30', 50°, 56° 30', 59° and 60°, and for the obtuse. 130° 30' to 120°.

7. *Etchings upon thin sections of scapolite from Malsjö in Wermland.*

Upon the thin sections of scapolite taken nearly parallel to the main axis and treated with hydrofluosilicic acid, the etchings which were observed between the strongly appearing grooves parallel to the main axis, resembled long, much distorted and overlapping grooves which were at times united into a snake-like net-work. Chlorine gas, likewise, produced very irregular, jaggedly roundish and longish depressions and caused cleavage grooves parallel to the main axis to appear strongly.

8. *Etchings upon thin sections of elaeolite from Laurwig in Norway, produced by chlorine gas (magnified to the 400th power.)*

After removing the mass of separated gelatinous silica and the crystals of sodium chloride imbedded in it, (usually these are octahedrons,) there appeared upon the thin sections of elaeolite a parallel rectilinear grooving, besides the rare but broad rectangular cleavage crevices. And in the band-shaped spaces between the grooves appeared long rectangular depressions and protuberances, sometimes pointed at one end or many-sided, and more or less regularly prism-shaped and parallel to the grooves. Among these in some few places, tolerably regular hexagonal prisms were observed. Upon one of these prisms a secondary pyramid appeared on one of the basal planes. (See plate II, Fig. 15).

9. *Etchings on a thin section of Leucite from Vesuvius.*

(Observed when magnified to the 400th power.)

Upon the leucite there appeared, after treatment with chlorine gas, very tiny and closely crowded, round or polygonal depressions, and after treatment with hydrofluo-silicic acid a very close, delicate polygonal network (See Plate II, Fig. 2).

10. *Etchings on thin sections or cleavage fragments of feldspar.*

(Magnified to the 400th power.)

After treatment with hydrofluoric gas and then with boiling water, the most perfect cleavage planes of sanidine from the phonolite of Tannberg (at Tollstein, formerly Kingdom of Rumburg) showed either long, polygonal, sometimes six-sided

depressions (of the ordinary outline of the clinopinacoid face) or groove-like, very slender and close, parallel depressions. Those of adularia from St. Gotthard, and of ryacolite from Vesuvius, showed for the most part groups of parallel, pointed (tower-like) and wedge-shaped depressions. or more rarely rows of short prisms and cones, projecting sharply out of the etched surfaces.

After a similar treatment of microcline from Miask (amazonite) the characteristic microstructure appeared upon some of the cleavage planes (which were probably parallel to the basal plane) in the most beautiful manner, since the various internal and structual bands or parts were changed in various ways. But the microstructure of microcline appeared especially beautiful upon some cleavage planes of white striated feldspar (mentioned on page —) of the Bohemian museum which was labelled "Orthoclase from Karlsbad." Upon other cleavage planes of the same microcline (which were probably parallel to the klinopinacoid faces) there appeared closely crowded together and parallel, long, slender, spindle-like, cylindrical depressions, which by a gradual lessening of length were changed into scaly etchings arranged like tiles.

Upon the most perfect cleavage planes of albite from Dauphiné, there appeared, after the above mentioned treatment with hydro fluoric gas and water, groups of slender, parallel spindle-shaped depressions crowded closely together, or of sharp edged subindividual crystal prisms or little tablets; while the etchings upon the cleavage planes of oligoclase from Ytterby were jagged, rhomboidal depressions and on the cleavage planes of anorthite from Vesuvius were polygonal, facet-like, roundish or net-shaped depressions.

Through the action of hydro-fluosilicic acid the trellis-like surfaces of the thin sections of amazonite were mostly etched in the form of delicate net-like depressions; upon the most perfect cleavage planes of albite from Dauphiné appeared peculiar sharp-edged, wedge-shaped etchings which were inclined to the plane of cleavage at a very sharp angle and were often distinguished by a regular arrangement in parallel rows, (see Plate II, Fig. 1,); and upon the oligoclase feldspar appeared either in slender grooves of diverse forms and variously placed, or lenticular, half moon-shaped, oval and quite rectangular depressions. The groove-like depressions were the more rare the less soda the feldspar contained. Upon the

thin sections of anorthite of corsite (from Corsica) only four-sided or roundish (almost rectangular) depressions of various lengths were to be noticed.

In conclusion I believe the remark would be appropriate, that the structural relations of single or twin silicate crystals as well as of many crystal groups and crystalline forms in thin sections, when treated for this purpose with hydrofluoric gas or hydrofluosilicic acid and water, are brought out in more clear significance and are more beautiful, since they present themselves unmodified.

V. Remarks upon the Application of some Older Methods for the Determination of Minerals in thin Sections.

1. *Upon the use of the red heat test for the separation of minerals containing iron (and manganese) from those free from iron (and manganese), for the proof of dichroism in the former if they offer colorless sections, and for the approximate determination of the melting point of minerals in thin sections.*

With a few exceptions all the minerals constituting the crystalline rocks may be divided into two groups, those which are free from iron (and manganese) and those which contain iron (and manganese).

In the *first* group belong chiefly the feldspathic minerals and the light varieties of mica, as well as wollastonite, apatite, calcite, dolomite and some pure clay silicates (chiastolite, andalusite, disthene, etc).

In the *second* group belong prominently minerals of the amphibole, augite and broncite series; also biotite (rubellan) chlorite, olivine, garnet, spinel, magnetite, chromite and titanic iron. And upon the borders of both groups might be placed mejonite (scapolite), cordierite and titanite, which minerals sometimes contain much, sometimes very little iron.

When the minerals of the first group appear in thin sections they present themselves in colorless, or, if they are impregnated with a pigment, in colored sections. The colorless mineral sections remain colorless even after the strongest heating or become white and slightly pellucid, while those colored by a pigment usually also appear colored after heating. But this coloring does not seem to be of a homogeneous character, is not usually evenly spread over the mineral section, but is commonly distributed in spots or intervals.

Minerals of the second group, when in thin sections, usually offer homogeneously colored sections, sometimes variously shaded in the crystal scales, but among these minerals appear also others, such that, colorless or only faintly colored, (many olivines, dichroites, epidotes, augites, diallages, enstatites), they might be mistaken for minerals of the first group. But since all minerals of this group contain more or less iron (or manganese), their thin sections can, through strong heat with the oxydation flame, be given a yellowish, reddish or brownish homogeneous coloring by which they can readily be distinguished from minerals of the first group.

The kind and intensity of color which comes by heating (of proper strength and continuance) upon the thin sections of minerals of the same species, but from different localities, sometimes determines with sufficient accuracy the relative quantity of iron (or manganese).

With the appearance of a homogeneous intense color the thin sections of many minerals of the second group acquire the peculiarity of showing a more or less strong dichroism and absorption of light. Which characteristic, before heating the minerals (so long as they were colorless or only faintly colored), could not be noticed at all, or only in a far less degree.

This process can be performed in the following way: Upon a small strip of platinum, slipped into the slit of a wooden handle, lay the thin section specimen of the size of 1½-3 □ mm and subject it, by means of the blow-pipe, to the oxidyzing flame for from 1½ to 3 minutes, so that for this length of time the specimen may be at a red heat; yet it is advisable to interrupt the heating after 1½ minutes and to investigate the specimen microscopically, and, in case it is colored, it should be put to the dichroscopic test; because by a longer continuance of heat many minerals are either colored so dark (gray or grayish-brown) that they lose in great measure their transparency and are no more fit for dichroscopic study, or they are entirely melted.

If the length of heating, which thin section fragments of equal size and under the above mentioned conditions require for fusion, has been determined for certain minerals, as steps in a scale of fusibility, then the melting-point of every other mineral in thin sections can be determined approximately by comparison with these; but one must observe that the contact of a mineral difficult of fusion with one easily fusible, demands heating in the high degree of the former mineral, and especi-

ally should this be observed in such minerals as usually hold an easily fused glass cement in rich masses.

I have made experiments upon the following mineral sections in regard to the change of color produced by heating and to the possible observation of dichroism, and in regard to their fusibility.

(*a.*) Upon the colorless olivine sections of nepheline pikrite from Devin at Wartenberg, which, after about two minutes of heating, received a homogeneous dark-yellow color, and then showed as strong dichroism as the yellowish-brown amphibole sections of many basalts.

(*b.*) Upon the nearly colorless, very pale-yellow olivine sections from Kozákov at Turnau. These became by heating, in reflected light, grayish-yellow, in places grayish-brown, in transmitted light grayish-yellow or grayish-brown (in places darker), and less transparent. Dichroism (dark grayish-yellow or grayish brown and light grayish-white with a streak of blue), and light absorption were distinctly observed.

(*c.*) Upon pale bluish-white almost colorless sections of blue dichroite from Orrijaerfvi in Finnland. These by strong heating acquired only a pale yellowish color, but, while before heating only a slight dichroism could be noticed, it appeared quite strong after the heating, when the changes of greenish-yellow, siskin-green and violet-blue were very beautiful.

(*d.*) Upon pale-bluish sections of blue dichroite from Bodenmais in Bavaria. These became, through heating, dark grayish-blue in reflected light, and in transmitted light dark grayish-brownish-violet and slightly pellucid, in some places opaque. Dichroism showed itself quite strongly thus: grayish-greenish-yellow and pale smalt-blue. Moreover, it was observed that a perfect cleavage appeared.

(*e.*) Upon the almost colorless sections of scapolite from Malsjö in Wermland, which became through heating an ashy-gray in reflected light, with a streak of violet, in transmitted light grayish-blue, in some places a brownish changing streak, and were scarcely translucent. Dichroism was scarcely noticeable either before or after heating.

(*f.*) Upon the grayish-white almost colorless sections of grayish-green epidote from Schwartzenstein in Zillerthal (Tirol). These, after some 1½ minutes of heating became grayish-yellow, but yet remaining literally transparent, showed a strong dichroism (change of color; pale bluish-green, emerald-

green and pale violet-brown), which was less distinctly observed before heating.

After 2½ minutes of heating the epidote thin sections became grayish-yellowish-brown very slightly pellucid, and after some 3 minutes of heating they became dark grayish-brown, opaque and with a curved distortion due to crumpling.

(*g.*) Upon thin sections of (black) augite from Wartha on the Eger (cut parallel to the pinacoid), colored brownish-gray with a streak of violet. After two minutes of heating the brownish shade on these appeared stronger and a quite distinct dichroism (greenish-yellow and violet-gray), and clear distinctions in the absorption of light were noticed. These, though in a less degree, could be noticed before heating.

(*h.*) Upon the almost colorless very pale-yellow sections of bronzite from Grauthal, which by heating became bright yellow, in the crevices a pale yellowish-brown, and presented a very distinct dichroism (grayish white and light brownish-greenish-yellow), especially upon the darker places.

The thin sections of micaceous rock from Libschitz which consist of biotite, amphibole, a tetragonal mejonite mineral, magnetite, apatite, and in some places rich brown glass-cement, were, after some three minutes of intense heating, changed into greenish glass, full of bubbles and containing colorless roundish bodies thickly crowded together, in which only biotite and amphibole could be distinctly recognized.

2. *Upon the use of cobalt-solution for identification of alumina and magnesia in sections of minerals free from iron (or manganese).*

The known reaction upon alumina and magnesia by heating the specimen treated with cobalt-solution upon coal can be applied to the investigation of the thin sections of colorless minerals free from iron; yet it must be noticed: (*a*) that the thin section specimens must be moistened many times with cobalt-solution and always very strongly heated if even a partially successful result is to be obtained, and (*b*) that thin sections having become dark or opaque by heating with cobalt-solution, can be made again transparent by being boiled with water or with a very dilute nitric acid.

The blue color given to aluminous minerals by heating with cobalt-solution appears stronger in reflected light than in transmitted light, because the action of the reagent mentioned usually reaches to every part of the surface of the thin section of the

mineral. And the rougher the surface is so much the more distinct is the desired effect. It seems advisable to expose the mineral thin section, before heating with cobalt solution, to the action of fluohydric gas or of chlorine gas according to the insolubility of the mineral in acids.

I have only made these experiments upon the thin sections of two minerals: quartz-andesite from Sebesvarallya in Hungary[1], which, heated with cobalt-solution and boiled in water, caused the bluish andesine section to be clearly recognized; and amazonite from Miask which was previously treated with fluohydric gas and water. The latter thin section heated with cobalt-solution and boiled in dilute nitric acid, appeared in many places bluishly transparent, yet the blue color was more strongly noticed in reflected light.

VI. ANALYTICAL GUIDE

FOR DETERMINATION OF MINERALS[2] APPEARING IN CRYSTALLINE ROCKS, BY THE NEW CHEMICO-MICROSCOPIC METHOD.

1. The specimen is a broken fragment, cleavage lamina or thin polished section of a homogeneous mineral.

If the specimen is a broken fragment or a cleavage lamina of a homogeneous mineral, take a piece the size of a barleycorn, crumble it into many little particles, lay these in the midst of a balsam layer spread upon an object-glass and made resinous by heating, cover the particles with a drop of 3 per cent. strong hydrofluosilicic acid of the size of a pea, observe whether a bubbling[3] occurs or not, and leave the object-glass, for the specimen to dry, in a place perfectly protected from dust. (In not too moist air the drying will require from six to twelve hours). Then subject the entire dried portion of the object and the upper surface of the somewhat smooth cleavage fragment to close microscopic examination magnified from 200 to 600 diameters.

It is to be noted that a satisfactory result can be obtained with the smallest grain of the specimen, although the drop of hydrofluosilicic acid must be correspondingly lessened in size

1 Received by kindness of Prof. G. Von Rath.

2 Since not all the minerals appearing in crystalline mixed rocks offered satisfactory results in these experiments this analytical guide is useful only for such minerals as have been actually investigated in their individual characteristics, or which allowed their characteristic reactions to be developed with the greatest probability, according to their nature and the laws involved.

3 Development of a colorless, odorless gas.

If the specimen is a thin polished fragment which measures about 2–4 □ mm, then heat the object-glass gradually and press the specimen carefully upon it with the point of a penknife, so that it will cling firmly and no little bubbles remain between it and the object-glass, and then continue exactly as indicated in the foregoing.

The remark may be permitted here that the smallest homogeneous portion of a thin section of a mineral treated with hydrofluosilicic acid must give perfectly reliable results.

NOTE.—*The minerals named below marked with an asterisk have already been investigated with hydrofluosilicic acid.*

A) The specimen is in the form of the finest splinters or the thinnest (more or less) transparent cut section.

On treating the specimen with hydrofluosilicic acid

A′ A continuous bubbling is noticed.

The silicic fluorides formed

a belong almost exclusively to calcium (Plate I, Fig. 6.)
The cleavage crevices of the specimen show
a a rhombohedral mineral................*Calcite.
b a rhomboidal mineral.................Aragonite.

b belong almost exclusively to magnesium (Plate I, Fig. 12.)
(The cleavage crevices of the specimen show a rhombohedral mineral)........................*Magnesite.

c belong in great part to calcium as well as magnesium.
The cleavage fissures of the specimen show a rhombohedral mineral..........................*Dolomite.

B′ No bubbling is noticed.

The silicic fluorides formed

d belong for the most part to lithium, in a small degree to potassium or even to sodium.
Scaly, colorless or light colored (from Roznau, peach-red) particles; for the most part thick, parallel grooved sections.............................*Lithia mica.

e belong for the most part to lithium and iron[1] (Plate II, Fig. 5, left side), in a small degree, sometimes to potassium.
Scaly, light-colored particles and little leaves, for the most part thick, parallel-grooved sections. *Lithia-iron mica.

f belong for the most part to potassium (Plate I, Figs. 1 and 2), often in a lesser degree to sodium (Plate I,

1 The iron fluoride crystals are colored dark yellow by the action of chlorine gas.

Fig. 4), and sometimes a small amount to calcium also.

a The mineral specimen consists of pliant leaves or scales; most of the cut-sections show a thick, parallel, rectilinear or undulating grooving; the silicic fluoride crystals formed are small and sparingly distributed (Plate II, Fig. 5, right side..................*Potash mica.

b The mineral specimen is of very perfect cleavage ; most of the cut-sections are distinguished by a *cross-banded* or *trellis structure;* the silicic fluoride crystals are larger and heaped up in quite large numbers along the trellis-like grooves.

Near the silicic fluoride of potassium appear some silicic fluoride crystals of sodium (Plate I, Fig. 16) *Microline.

g The mineral specimen is of very perfect cleavage; most of the longish-banded sections show no grooving, if they are quite homogeneous, but are sometimes composed of two long halves which in polarized light show different colors. The cut-sections, furnished with enclosures of grooved bands, offer, near the silicic fluoride of potassium, more or less silicic fluoride of sodium, at times also a little silicic fluoride of calcium .... *Orthoclase.

d Fragments perfectly cleavable, or cut sections of glassy appearance and fissured structure. A good deal of silicic fluoride of sodium is almost always found near the silicic fluoride of potassium.....*Sanidine.

e The mineral fragments show no perfect cleavage; the roundish (polygonal) cut sections are always clear or distinguished by beautiful enclosures arranged in the forms of wreaths (Plate II, Fig. 2) .*Leucite.

g belong almost exclusively to sodium.

Treated with chlorine gas, the mineral

a is not affected.

Perfectly cleavable fragments, whose surfaces often show etchings after treatment with hydrofluoric acid (Plate II, Fig. 1); usually the cut-sections have parallel rectilinear grooves, and in polarized light give variegated lamellar colors......*Albite (pericline).

b the mineral is strongly affected, and separates gelatinous silica which can be recognized easily by means of fuchsin solution.

aa Granular; quadratic, rectangular, hexagonal, and

trigonal cut-sections usually distinguished by a peculiar micro-structure, which (according to Knopp) become blue by the action of sulphuretted hydrogen.......Some nosean, some sodalite. (From nosean and sodalite may be recognized easily analcime.)

bb Fragments of short hexagonal prisms, rectangular and hexagonal sections often characterized by concordantly arranged outlines of microlite enclosures, which (according to Knopp) become blue by sulphur vapor....Some *nepheline (elæolite). Cut-sections rectangularly cleaved, parallel barred or fibrous (Plate II, Fig. 3), which after treatment with chlorine gas show peculiar etchings (Plate II, Fig. 15).............................*Elæolite

h belong for the greatest part to sodium, in a small degree to potassium.

Physical properties of the fragments and sections the same as under *g*, b, bb.......*Nepheline (elæolite).

i belong for the greatest part to sodium; but near these appear, sporadically, united silicic fluoride crystals of calcium.

The silica separated by chlorine gas in

a gelatinous. The specimen is strongly affected.

Physical properties same as under *g*, b, aa. Nosean, sodalite.

b not gelatinous. The specimen is very slightly affected. Fragments with perfect cleavage, sometimes with close and delicate parallel grooving. The majority of them in cut-sections banded, usually with parallel grooves, and showing parti-colored lamellar structure in polarized light (Plate I, Fig, 17.).....*Oligoclase.

k belong for the most part to sodium, in smaller degree to calcium, but not materially different.

The silica separated by chlorine gas

a is not gelatinous.

Fragments colorless or light colored, with perfect cleavage, sometimes with close and delicate parallel grooving. The greater part banded and in thin sections showing in polarized light variegated bands of color..................................*Andesine.

b is gelatinous. The specimen is strongly affected.

Mostly blue grains; quadratic, rectangular, hexag-

onal and trigonal, cut sections usually distinguished by a blackish-blue or reddish, close trellis-work. Hauyne.

l belong to calcium and sodium, in all probability of almost equal parts, but the greater part to calcium and the lesser, though not essentially different, to sodium.

The silica separated by chlorine gas is

a not gelatinous.

Fragments colorless or light-colored, and with perfect cleavage, often with delicate and close parallel groovings; the cut-sections for the most part striated with parallel, delicate, close grooves, and in polarized light displaying parti-colored lamellar structure. (Plate I, Fig. 19)....................*Labradorite.

b gelatinous.

Physical properties same as under *k*, b..Some hauyne.

m belong for the most part to calcium, in a much smaller degree to sodium, sometimes also a small quantity to magnesium and iron.

The silica separated by chlorine gas is

a not gelatinous. The specimen is strongly affected.

Fragments colorless or light colored, with perfect cleavage; for the most part the cut-sections are banded with parallel grooving, and show in polarized light a parti-colored lamellar structure. (Plate I, Fig. 20) ....Some *anorthite.

b gelatinous, The specimen is strongly affected.

Most of the tetragonal and rectangular cut-sections are colorless, yellowish or brownish; the colorless ones are colored yellow by red heat, at least around the edges and in the crevices. ....*Melilite.

n belong almost exclusively to calcium (in a much smaller quantity to sodium, magnesium, iron and manganese.)

By action of chlorine gas the specimen

a is very slightly affected.

aa Blackish, sharp-angled grains, mostly with a grayish-white translucency and a sub-metallic lustre, which give a titanium reaction or cut-sections of tesseral crystals of a grayish-white (yellowish or brownish) color and dark angles......Perofskite.

bb Reddish, brownish, blackish brown-to-black grains which give no titanium reaction; reddish or brownishcut-sections of tesseral crystals..Some garnets.

b Quite strongly affected, yet *without* the separation of *gelatinous* silica.

aa Tetragonal prisms or columnar particles; cut sections grayish-white; rectangular and tetragonal, and parallel-barred or fibrous, showing characteristic etchings after treatment with chlorine gas. (Plate II, Fig. 4)......................*Scapolite.

bb Hexagonal prisms; cut-sections rectangular and hexagonal, colorless or furnished with rows of powder-grains, which after treatment with chloine gas, or with hydrofluosilicic acid, show characteristic subindividual crystals (etchings). (Plate II, Figs. 16–20)........................*Apatite.

gg Yellowish, greenish or brownish, short monoclinic tablets or prisms which give the titanium reaction; cut-sections pale yellowish, greenish or brownish-gray (usually spindle-shaped) of monoclinic forms *Titanite.

dd Colorless or light colored fragments with perfect cleavage, often with parallel grooves; cut-sections for the most part with parallel rectilinear groovings, and showing in polarized light a variegated lamellar structure..............Some *anorthite.

g Quite strongly affected and *with* the separation of *gelatinous* silica.

aa Tetragonal prisms or columnar fragments; grayish-white or pale yellowish or greenish tetragonal and rectangular cut-sections or parallel-striped or fibrous particles........................*Mejonite.
Here also might belong some............Melilite.

bb Fragments of colorless or white monoclinic crystals or bar-like to fibrous aggregates..*Wallastonite.

o belong almost exclusively to magnesium (the silicic fluorides are *not colored* by chlorine gas, or are only colored slightly an orange yellow).

a Grains, with little evident cleavage, very hard; cut-sections mostly rectangular or irregular, roundish, which after red heat show a marked dichroism (Plate II, Fig. 10)............................*Dichroite.

b Pliant, very soft and flexible leaves, scales or groups of scales, white or pale colored; cut-sections mostly striped.....................................*Talk.

g Grains with perfect cleavage, hard, pale-greenish or

yellow; cut-sections with parallel rectilinear grooving..............................Some enstatite.

p belong to magnesia, iron and potassium.

Short, dark-colored prisms with evident cleavage on the basal planes and hexagonal leaves (Plate II, Fig. 6). Some *biotite.

q belong to magnesium and iron, sometimes also in a slight degree to calcium (the silicic fluoride crystals belonging to iron are colored orange yellow by chlorine gas and are blackened by sulphide of ammonium gas.

The silica separated by chlorine gas is

a gelatinous.

Cut-sections colorless, yellowish, greenish, brownish, showing dichroism after red heat, clear or marked with non-rectilinear cleavage crevices. These sections after treatment with hydrofluosilicic acid show often subindividual crystals (etchings) (Plate II, Figs. 11 and 12)........................*Olivine.

b not gelatinous; sometimes the specimen is not at all affected.

aa *Hard* grains, which present *no, or only an imperfect cleavage*; cut-sections show *tesseral* crystals upon which an imperfect cleavage, or none at all, is to be observed.

△ Grains blood-red or dark brown; cut-sections dark red and brownish....*Pyrope and some garnets.

△△ Grains dark green, blackish-brown and blackish; cut sections greenish, grayish or brownish...... *Pleonast (picotite).

bb Greenish hexagonal tablets, of *very perfect cleavage*, soft, pliant scales, or leafy or scaly grooves; cut-sections greenish with parallel groovings or stripes, or delicate scaly spangles .....*Chlorite.

gg Grains with rather perfect or *perfect cleavage*, quite hard, greenish, blackish-green or greenish-black; cut-sections grayish-white, light or dark green, with very close parallel, rectilinear or columnar groovings, or fibrous.

The silicic fluoride crystals are colored orange yellow by chlorine gas.

△ in a small part only................Enstatite.

△△ in a greater part (Plate II, Fig. 9)*Bronzite.

△△△ in the greatest part............*Hypersthene

r belong to calcium, magnesium and iron, or calcium and iron.

Delicate cleavage fragments or cut-sections show

aa either before or after heating a very strong dichroism. The silica separated from the heated specimen by chlorine gas.

△ is gelatinous.

Very perfectly cleavable, hard, usually grayish-green, monoclinic crystals, or barred or granular aggregates; cut-sections grayish or greenish-white, with rectilinerally parallel but very light and delicate groovings..............*Epidote.

△△ not gelatinous.

Black or blackish-green, monoclinic, columnar crystals of various lengths; cut-sections greenish, grayish, yellowish or brownish, upon which quite perfect cleavage crevices are usually seen. (Plate II, Fig. 7). These intersect in regular diagonal sections at an angle of 124°30′ *Amphibole.

bb none or only slight dichroism.

△ Crystals greenish-black, black, or blackish-brown, monoclinic, short columnar; greenish, yellowish, brownish or grayish cut-sections whose cleavage crevices are often quite rectilinear. They intersect in regular diagonal sections at an angle of 87°6′.. *Augite (pyroxene).

△△ Grains thick, plate-like, dark-gray, brownish or blackish, perfectly cleavable in one direction, and striped on the most perfect cleavage surfaces, or fibrous; cut-sections with parallel and sharply rectilinear but light groovings in one or two directions (Plate II, Fig. 8)......*Diallage.

s The silicic fluorides are lacking entirely or appear only very rarely.

a Cut-sections pale or colorless; changed by hydrofluoric gas effervesce in sulphuric acid..Pure alumina silicate. like *chiastolite (Plate II, Fig. 13), disthene, andalusite. etc., which may sometimes be distinguished by etchings.

b Dark red hexagons or irregular particles, or scales with tattered edges (in cut sections)......Hematite.

g Brown or yellow-brown, mostly earthy particles (in thin sections)........................Limonite.

B) The specimen is in the most fragile splinters or the thinnest cut-sections.

A′ Black, opaque.

a Is distorted by heating (sometimes leaving a red portion behind it). This is

aa Amorphous.... ....Anthracite, coal.

bb scaly............................Graphite,

b Is not changed by treating, or only colored brownish or reddish at the edge............Magnetite.

B′ Blackish-brown, slightly translucent.

a A rhombohedral cleavage disclosed by the cleavage crevices, and, heated with a drop of sulphuric acid, colors the latter blue at the edge (according to Sandberger).....................Titanic iron.

b Is tesseral and gives chrome reaction..Chromite.

2. The specimen is a fragment or a portion of a thin-section of a crystalline rock.

If the specimen is a crystalline rock out of which the individual mineral to be investigated can be selected, in the form of very tiny but perfectly homogeneous particles, by help of strong magnifying glass; or if it is a thin section out of whose sections the smallest homogeneous particles can be cut; in either of these cases, the separate investigation of each mineral, for the proof of its real nature, should be undertaken as the surest way; but the fulfillment of all the conditions for an infallible result (namely, purity of the hydrofluosilicic acid used, as well as of the Canada balsam, and protection from dust) is to be the more carefully observed the smaller the specimen to be studied.

If the above mentioned specimen, in the form of a thin section, consists only of minerals each of which contains other metals (or one other metal) a separation and separate investigation of the individual minerals is not usually necessary, but the general treatment of it with hydrofluosilicic acid usually leads to perfectly satisfactory results. For example, if the specimen is a variety of basalt, which consists of augite or amphibole, magnetite and nepheline, or of augite and amphibole, magnetite and glass substance, (magma) and it be treated with hydrofluosilicic acid, there appear, constantly, in the first case, besides the silicicfluorides of calcium, magnesium and iron (arising from the augitic ingredient), silicicflu-

oride crystals of sodium, sometimes also, in less quantity, those of potassium, while in the latter case, the more or less rich appearance, or sometimes entire lack of silicicfluorides of the alkalies (and the insolubility in chlorine gas), sufficiently characterize the chemical nature of the glass substance (magma). If the specimen is a variety of porphyry which contains besides quartz and monoclinic feldspar, only one triclinic feldspar, and it is treated with hydrofluosilicic acid, a tolerably certain conclusion can be drawn concerning the chemical nature of the triclinic feldspar from the quantitative proportions of the silicic fluoride crystals of calcium and sodium.

These cases in which a common treatment of several minerals with hydrofluosilicic acid allows the chemical nature of the minerals to be recognized, often present themselves to the microscopical petrographer in investigating thin sections of rocks; but far more frequently the preparation of such cases lies in the hand of the investigator.

In the thin sections of most rocks particles appear in some places which allow a general treatment with hydrofluosilicic acid for the proof of the chemical combinations of their mineral mixed portions. And such particles however small they may be can be cut out of the thin sections and investigated.

If the thin section specimen of a crystalline rock, in whose minerals occur one and the same, or several similar metallic elements, be treated with hydrofluo-silicic acid, the totality of silicic fluoride crystals formed affords in all cases the analogy of a partial chemical Bausch-analysis.

But in most cases more is aimed at in treating the specimen with hydrofluo-silicic acid than that a Bausch-analysis may be afforded the petrographer, since by certain precautionary measures—especially if the hydrofluo-silicic acid drop has spread only a very little over the edge of the thin section and if it is dried in a perfectly horizontal position on the object-glass and in perfect quiet,—the silicic fluoride crystals formed do not mingle regardless of order, but for the most part are formed on the upper surface of that mineral to which they belong. In such cases characteristic forms of partial chemical analyses of the individual minerals have been obtained.

VII. Remarks upon the Importance of the Explained Methods for Determinative Mineralogy and Analytical Chemistry.

Upon the basis of many analytical experiments which I have made according to the above methods upon many and various (about one hundred) minerals, I believe I may be allowed to express the hope that my elements of a new method for the chemico-microscopic analysis of rocks and minerals may offer many suggestions not unimportant to the petrologist and mineralogist, and also in some measure to the analytical chemist, and that they are worthy of a continued and broader development (by means of other valuable agents)[1]

Without mentioning the amount of time and many requisites —a favorable place for work, the necessary apparatus, and numerous reagents—which the chemico-analytical experiments undertaken upon minerals in the usual way demand, the mineralogist as well as the petrographer is obliged to experiment upon one or a few grains of the specimen, and, after one or more failures or experiments producing only negative results, must discontinue his attempts on account of lack of material. And in such a case the best chemist cannot aid him unless the spectroscope can offer assistance.

On the other hand, our "universal method" (and at times also the methods based upon the application of fluohydric gas) applied to the smallest specimen, offers a safe analysis of the metallic elements, whether they appear free or in monoxides, or in their manifold salts, in hyperoxides or their analagous sulphur, selenium, tellurium, arsenic and antimony compounds; which, with the coöperation of the physical properties, usually suffices for the determination of the mineral species. Moreover our method requires no special locality for the work, no large number of implements and reagents, but—besides Canada balsam, object-glasses and a spirit lamp—only a caoutchouc flask filled with perfectly pure hydrofluo-silicic acid of 3 per cent. strength, and a caoutchouc stick kept in a caoutchouc tube. And the whole time required for investigating a mineral —without counting the time required for drying the drop of acid—is in most cases only from five to ten minutes.

Although I have already examined more than a hundred mineral species by means of hydrofluo-silicic acid, still I consider

1 Preeminently do experiments with acids analogous to hydrofluosilicic acid, especially with borfluoric and hydrofluotitanic acid, promise favorable results.

this only a small fraction of the work yet to be completed in order to be able to publish a practical and perfectly reliable key for the determination of all minerals according to the above described methods. But I hope in a few months to reach the desired end. I will here confine myself to a few hasty remarks which indicate the foundations for the projected key for the determination of mineral substances, and which will contain the requisite directions for many cases.

(*a*.) The silicic fluorides known up to this time--besides those appearing in petrologically important minerals, and specified on pages 17 to 23—are the following:

The silicic fluoride of ammonium (plate I, fig. 1, s. t,) ($[NH_4]_2$ $Si\ F_6$) must be dimorphous (Marignac, Ann. chem. phys., [3] *LX* —301 and Jahresb. über Fortschr. d. Chem. 1860 [pro 1859], page 107, and 1861 [pro. 1860], page 98). From the pure solution it crystallizes according to Marignac in tesseral combinations of octahedrons with hexahedrons; from solutions, on the other hand, which are rich in hydro-fluoric gas or fluoride of ammonium, in combinations of the hexagonal system: $\infty P.\ P.\ 0P.\ \infty P.\ P.\ 2P.\ 0P.$ According to Marignac's report $P: P. = 139^\circ\ 36'$, $2P: 2P = 127^\circ\ 25'$, $0P: P = 136^\circ\ 20'$, $0P: 2P = 117^\circ\ 39'$. Through re-crystallization the hexagonal crystals become tesseral.

From the solutions diluted with surplus fluoride of ammonium, the silicic fluoride of ammonium crystalizes in double-folded, quadratic combination forms ($\infty P. 0P$, rarely $\infty P \infty$), which many times appear cube-shaped (Jahresb. über Fortschr. d. Chem., 1860 [pro. 1859], page 107).

I obtained the silicic fluorides of ammonium (with a surplus of hydrofluo silicic acid), always in large sharp-edged tesseral forms ($\infty 0\ \infty. 0$), which could not be distinguished from the silicic fluorides of potassium, unless it is permissible to designate the unusually beautiful scale-structure and the step like nature of the surfaces observed on the imperfectly formed crystals of silicic fluoride of ammonium as special marks of difference.

Since the ammonium salts are, by their volatility when heated, to be distinguished easily and separated from the potassic salts, the isomorphism of their silicic fluorides is not destroyed by the investigation of the mineral substances. If, for example, a thin particle is to be tested for potassium, the specimen is heated before treatment with hydrofluo-silicic acid or with fluohydric gas.

The silicic fluoride of silver ($Ag_2\ Si\ F_6+4\ H_2O$) crystallizes in quite flat pyramids of the tetragonal system, which are liable to deliquesce in the air. (Marignac, Comptes rendus XLVI—854 and Jahresb. über Fortschr. d. Chemie v. Kopp u. Will, 1859 [für 1858], pag. 145, and 1860 [f. 1859], pag. 107).

The silicic difluoride of mercury ($Hg_2\ Si\ F_6+2H_2\ O$) prepared by the solution of carbonic oxide of mercury in fluosilicic acid and evaporation of the solution, appears in very transparent prismatic crystals.

The silicic fluoride of mercury ($Hg\ Si\ F_6+6H_2\ O$) crystallizes in water-clear rhombohedrons, arranged like stairs, and liable to deliquesce on exposure to air, and these are formed when the solution of quicksilver oxide in hydrosilicic acid is so concentrated that the crystals of the above-mentioned compound begin to separate, and also when the solution is left to itself at a temperature not exceeding 15°. (Gmelin's Handb. d. Chemie, pag. 865).

The silicic fluoride of lead: ($Pb\ Si\ F_6+4H_2\ O$) crystallizes according to Marignac, (Ann. Min. [5] XV, 221 u. Jahresb. über Fortschr. de Chemie, 1860, pag. 107), in forms of the monoclinic system, and especially in the combinations: $0P.\ \infty P,\ 0P.\ \infty P.\ \infty P2.\ P\infty.—P.P.\ 2P\infty$. In the clinodiagonal chief section $\infty P{:}\infty P=64°\ 46'$, $\infty P2{:}\ \infty P2=103°\ 30'$, $P{:}\ P=100°\ 2'$, $—P{:}—P=101°\ 23'$, $0P{:}\ \infty P\infty=91°\ 30'$, $0P{:}P=130°\ 29'$, $0P{:}—P=131°\ 24'$, and $0P{:}\ 2P\infty=128°\ 6'$. The crystals are easily cleavable parallel to $0P$ and less easily parallel to $\infty P\ \infty$.

The silicic fluoride of lead $Pb\ Si\ F_6+2H_2\ O$ is, according to Marignac (as above), in some cases monoclinic, and usually appears in the form $\infty P.\ 0P$, rarely with $\infty P\infty$ or $P\infty$. In the clinodiagonal chief section $\infty P{:}\ \infty P=71°\ 48'$, $0P{:}\ \infty P\infty=103°\ 44'$, $0P{:}\ \infty P=95°$, $0P{:}\ P\infty=127°\ 55'$.

The large, beautiful, sharp-edged and smooth-faced crystals of *silicicfluoride of lead* (magnified to the 400th power) which I obtained from the lead-glan[illegible] om Pribram, by means of hydrofluosilicic acid, had the [illegible]s: $\infty P.0P,\ \infty P.\ 0P.\ \infty P\infty,\infty P.\ \infty P\infty\ mP.\ mP\infty$. The prisms and needles were in radial groups and bore a great sim[illegible]arity to the aggregate forms of silicicfluorides of calcium and strontium.

Treated with tolerably dilute sulphuric acid, they were changed into little secondary forms in a confused mass of delicate needles (anglesite?) and were soon colored grayish by hydro sulphuric gas.

The silicicfluoride of copper ($Cu\ Si\ F_6+6H_2O$) crystallizes according to Marignac (Ann. Min. [5] XV—221) in forms of the hemihedral hexagonal system, usually in the combination forms $\infty P2.\ R;\ R:\ R=125°\ 30'$. If the silicicfluoride of copper crystallizes at 50° T, it appears as $Cu\ Si\ F_6+4\ H_2O$ in forms of the monoclinic system.

The rare, almost colorless crystals of silicic fluoride of copper, formed from chalkosine, bornite and tetrahedrite by hydrofluosilicic acid *being greenish-blue* or *bluish-green in reflected light* were usually imperfectly formed and always *deliquesced on the edges and corners*. After treatment with chlorine gas they appeared bluish-green in transmitted light.

The silicic fluoride of nickel ($Ni\ Si\ F_6 + 6\ H_2\ O$) formed by dissolving $Ni\ CO_3$ in $H_2\ Si\ F_6$, crystallizes according to Marignac (Ann. Min. [5] XV—262; Jahresb. über Fortschr. der Chemie v. Kopp u. Will, 1860, page 103, and Gmelin's Handb. d. Ch. p. 571) in forms of the hemihedral hexagonal system, and in greenish rhombohedrons and hexagonal prisms; is easily soluble in water. R: R=127° 34',—2R:—2R=97° 10', R:∞ R =116° 13', ∞ R: —2R=131° 23', 0R: R=149° 14', 0R:—2R= 130° 0'. Specific gravity=2.109 (Topsoë).

The crystals of silicic fluoride of nickel formed from ullmanite and carbonate of nickel were, magnified to the 400thpower, quite large, either prism-shaped, needle-shaped or similar to a rhombohedron combined with the basal face, very sharp-edged and smooth-faced, almost colorless in transmitted light, *grayish green in reflected light*, and usually covered with a dark-gray granular substance which is greenish-yellow and delicately granular in reflected light.

By the action of chlorine gas they acquired a more or less greenish, in some places emerald-green color, and treated with dilute sulphuric acid were changed into small secondary forms in a close network of delicate, long, grayish needles; in reflected light this network appeared light grayish-bluish-green.

The silicic fluoride of cobalt ($Co\ Si\ F_6+6H_2\ O$), formed by dissolving carbonate of cobalt in fluosilicic acid appeared (according to Berzelius) in pale-red rhombohedrons and six-sided prisms which are easily soluble in water. According to Grailich (Kryst. opt. Unters. Wiens; u. Olmütz, 1858, 75), R: R (Polk.)= 126° 59', R: ∞P2=116° 30'. The crystals are indistinctly cleavable parallel to ∞ P̂2. The specific gravity=2.067 (Topsoë) (Gmelin's Handbuch der Chemie, page 516).

The silicic fluoride of cobalt formed from cobaltine by means of hydrofluosilicic acid, appeared (magnified to the 400th power) in large, sharp-edged, smooth-faced crystals, which seemed to be isomorphous with the silicic fluoride crystals of nickel and iron. While the small crystals were almost colorless the larger presented a distinct, pure bluish or pale-violet color.

By action of chlorine gas the silicic fluoride crytals of cobalt were colored for the most part pale violet-brown, and dissolved largely into a violet-red liquid. Treated with rather dilute sulphuric acid, they gradually lost their bluish color, became colored pale rose-red, and about the borders merged into delicate grains.

The silicic fluoride of cadmium ($Cd\ Si\ F_6+6H_2\ O$) crystallizes, according to Marignac, (Compt. rend. *XLVI*—854, and Jahresb. u. Fortschr. d.Chemie. 1859 [145] and 1860 [107]), in long prism-shaped, transparent forms of the hemihedral hexagonal system, which are very easily soluble in water.

The silicic fluoride of zinc ($Zn\ Si\ F_6+6H_2\ O$) crystallizes, according to Marignac (Ann. Min. [5] XV, 221 and Jahresber. über Fortschr. der Chemie. v. Kopp und Will, 1860, page 108), in hemihedral hexagonal forms, usually in the combination forms $\infty P2.\ R$ or $\infty P2.\ R.\ 0R$ and parallel to $\infty P2$ is distinctly cleavable. $R: R=127°\ 16'$. Specific gravity=2.104. Easily soluble in water.

Treated with rather dilute sulphuric acid, the crystals of silicic fluoride of zinc, which I obtained from sulphuret of zinc by means of hydrofluosilicic acid were very slowly changed.

The silicic fluoride of tin appeared in long prisms, which are very soluble in water, and by evaporation separate into oxide and silica. (Gmelin's Handbook of Chemistry, p. 153.)

The silicic fluoride of molybdenum, obtained from molybdenite by means of hydrofluosilicic acid, appears (mag. to the 400th degree) in large sharp-edged, smooth-faced colorless crystals which show greatest similarity to the combination forms of R. 0R and R. ∞ P 2. And the delicate leaves of molybdenite became transparent and of a beautiful grayish-blue color after treatment with hydrofluosilicic acid.

The silicic fluoride of platinum resembles a yellowish-brown gum. (Gmelin's Handbook of Chemistry, p. 1186).

From the foregoing it is evident that the silicic fluorides of copper, cobalt, zinc, nickel and manganese are isomorphous

(for the terminal edges of their fundamental rhombohedrons give the following values: 125° 30′, 126° 59′, 127° 16′, 127° 34′ and 128° 20′), and they appear, with the exception of silicic fluoride of copper, in very similar combination forms (mostly ∞ P2. R and R. 0R). And since these silicic fluorides are also related to those of iron, cadmium, magnesium and possibly several other metals, the series of those metals which appear in such silicic fluoride crystals as can hardly be distinguished by their same types is quite large.

But, since it is possible to separate successfully from each other the isomorphous silicic fluorides of calcium and strontium, and those of iron, manganese and of magnesia, in a very simple way, it is to be hoped that a simple and suitable reaction for all the silicic fluorides of metals of the hemihedral, hexagonal crystal series can be found.

Of the few and quickly made observations and experiments which I made with this end in view, I will mention the following: (*a*) All the specified, hemihedral hexagonal silicic fluorides were almost colorless in transmitted light if they appeared in small quantities, but, on the other hand, when they were brought forth in greater quantities or in larger crystals (from minerals easily decomposed by fluosilicic acid) a distinct, pale-violet-blue or violet-red color appeared upon the silicic fluoride crystals of cobalt; upon those of nickel, a gray color with a faint tint of brown; upon those of copper, a gray with a strong shade of bluish-green, while upon the silicic fluoride crystals of the other metals, except a grayish tint, no color was observed.

(*b*) In reflected light, of the crystals of the silicic fluoride metals mentioned under (*a*), those of copper appeared bluish-green, of nickel, greenish gray, of cobalt, bluish-gray.

(*g*) By the action of chlorine gas were the silicic fluoride crystals of copper colored bluish green, those of nickel, emerald-green or dark-grayish-green, those of cobalt, violet-brown and those of iron, orange-yellow, but in the presence of cobalt and nickel, citron-yellow or greenish-yellow. The silicic fluoride crystals of manganese contained a faint shading of rose-red, while those of zinc and magnesia remained colorless or became grayish-white.

(*d*) By sulphuric acid the silicic fluorides of most metals were gradually dissolved, though the silicic fluoride of cobalt gave a violet-red liquid. Lastly, hydrosulphuric acid and sul-

phide of ammonim gas were used; but the results were not so significant that a repetition of the experiment seemed necessary.

Since the silicic fluoride of lead appeared in monoclinic and the silicic fluoride of silver in tetragonal crystal forms, the distinction of the silicic fluorides of the two metals from each other and from the hemihedral hexagonal silicic fluorides of the above named metals, according to the form type, is possible. Moreover the silicic fluoride of lead shows itself in such a way that when treated with tolerably dilute sulphuric acid it is changed into little secondary forms in a net-work of delicate needles (anglesite?).

(b) By the treatment of minerals with hydrofluosilicic acid and by the observation and finally the further separation of the silicic fluoride crystals formed, the knowledge of the electro-positive elements of minerals is gained; therefore for determinative mineralogy (in general) a classification of the mineral kingdom—which is analogous to the classifications explained for petrologically important minerals—in groups according to the electro-positive elements, appears to be worthy of consideration.

(c) There are only a few minerals, which—like baryta, celestine and quartz—are not at all affected by the three per cent solution of hydrofluo-silicic acid; on the other hand some minerals are decomposed by it, which would hardly have been expected; as for example tourmaline, spinel in thin sections, sphalerite, and pyrite in fragments.

(d) The sesquioxides of aluminum, of iron, and as it appears of other minerals also, are quite changed into silicic fluorides by fluosilicic acid; but these *do not* appear to show themselves altogether in crystal forms. This permits the mineralogist as well as the chemist to distinguish the smallest quantity of any oxide, (for example, of iron which is easily changed into silicic fluoride crystals which remain stable in the air) in any (iron) salt, whether soluble or insoluble in acids.

(e) The quantity of silicic fluoride crystals formed under similar conditions and of the silica separated from silicates, offers an excellent means for judging the insolubility of the determined minerals in hydrofluo-silicic acid, and of estimating the importance of the determinations.

The reactions mentioned under (a) and in connection with the physical properties of the specimens should in most cases suffice for the determination of minerals.

(f) If the specimen is a simple salt soluble in water, the crystal form of the original salt, or that changed only by the percentage water of crystallization which it has absorbed, can, after the treatment with hydrofluo-silicic acid and drying of the specimen, be brought to appear in conjunction with the silicic fluoride crystals of the electro-positive elements. Thus, for example, if one should treat the larger grains of sodium chloride, Chile saltpeter, glauber salt, borax, etc., with hydrofluo-silicic acid (each specimen separately), he will obtain near the hexagonal silicic-fluoride crystals of sodium (appearing in each specimen), in the first specimen little cubes of chloride of sodium, in the second rhombohedrons of sodium nitrate, in the third monoclinic needles of glauber salt, and in the fourth borax crystals recognizable through their form types. If kieserite be treated with hydrofluo-silicic acid, one obtains near the silicic-fluoride crystals of magnesium, epsomite also.

(g) If the specimen is a compound salt soluble in water, there appears near the silicic fluoride crystals of the individual metals, single salts of mineral specimens in their original crystal forms, or in these changed only by the absorption of the water of crystallization. Thus, for example, after the treatment of polyhalite with hydrofluo-silicic acid, I have also noticed at the first glance striated groups of beautiful gypsum crystals near the silicic fluoride crystals of potassium, magnesium and calcium.

(h) If the mineral specimen is a carbonate, on its treatment with hydrofluo-silicic acid, a very strong effervescence is in most cases to be noticed, by which the electro-negative elements, especially the colorless and odorless carbonic acid gas are sufficiently identified.

A more or less strong ebullition was observed, on treatment with hydrofluoric acid, of potash, soda, calcite, magnesite, dolomite, dialogite, witherite, strontianite, cerussite and azurite; on the other hand no development of gas could be noticed in the case of siderite, mesitine and smithsonite, although after the drying of the hydrofluosilicic acid drop, the formation of silicic fluoride crystals followed (less richly) from the carbonate last mentioned.

In the cases explained under (f), (g) *and* (h), *our methods offer a perfect chemical analysis of the mineral substance.*

(i) All minerals of the classes of glance, pyrite, and blende (and from the metals of pure silver) which I have heretofore investigated with fluosilicic acid, were more or less strongly

affected and gave a corresponding quantity of silicic fluoride crystals. The most beautiful and the largest crystals were obtained from iron, cobalt, nickel and lead minerals, the rarest from minerals containing copper, (chalcosine bornite, tetrahedrite). Pyrite fragments, however, form an exception since they gave only a few small silicic fluoride crystals of iron.

(k) If the material to be examined is in considerable quantity and one wishes to test the electro-negative element also, for a perfect mineral analysis, this can be done with the ordinary reagents, either upon a watch-glass (for the proof of Cl, Br, I, SO_3, P_2O_5, B_2O_3), or in a glass tube (for proof of F, S, Se, Te), or upon coal (for proof of N_2O_5, As_2O_5, Sb_2O_5, As, Sb), or in a salt of phosphorus lead (for proof of SiO_2, TiO_2, MoO_3, WO_3).

(l) If this be done to prove the alkalies only (even if they appear in the smallest quantity), in a silicate (for example amphibole, wollastonite), or to establish their absence, then treat the silicate specimen (in little grains) with hydrofluoric gas. Extract the silicic fluorides of the alkalies by gradually boiling in water upon a platinum cover and place this decoction reduced at a moderate temperature to one drop upon the hard plate (of Canada balsam) of an object-glass.

It is to be noticed here that in many cases the silicic fluorides of other metals contained in the specimen may appear. Thus I have always obtained from calcareous silicates rich in silicic acid (as oligoclase) a small quantity of silicic fluoride of cal cuim; on the other hand, on analogous treatment of anorthite and wollastonite no needles of silicic fluoride of calcium were to be found. And the slow development of large gas bubbles on treatment of anorthite and wollastonite changed by HF was a proof that only a simple calcium fluoride had formed in the latter minerals. But by treatment of chondrodite, olivine and rhodonite with hydrofluoric gas and then with a cold drop of water, long prism-shaped silicic fluoride crystals of magnesium (iron) and manganese were produced.

Illustrations of parts of Microscopic Preparations Showing

(*a*) The silicicfluoride crystal types of metals appearing in petrologically important minerals and

(*b*) The characteristic changes which are effected upon the upper surface of thin sections or cleavage sections of petrologically important minerals either by hydrofluosilicic acid or by hydrofluoric gas.

[PLATES I AND II.]

Explanation of Plate I.

[NOTE. In the reproduction of the plates, some of the Greek letters employed by the author to designate the figures have become indistinct. These Greek letters, however, are confined to Fig. 4, Plate I. The reader may restore them all by noting that the small crystals in "Fig. 1," of Plate I. are designated in the original from left to right in the following order: Alpha, epsilon, iota, rho, nu, mu, sigma, tau, which in the following explanation are designated by a, e, i, r, n, m, s, t].

Fig. 1. Silicic fluoride of *potassium*, observed and represented when magnified to the 400th power: a, i, from the preparation of Prof. Stolba (by recrystallization on the object-glass); e, m, n, r, (∞ 0. ∞ 0 ∞, 0. ∞ 0∞.) from the water decoction of a dark-green biotite, changed by hydrofluoric gas. s. and t. are crystals formed by the recrystallization of silicic fluoride of *ammonium*.

Fig. 2. Silicic fluoride of *potassium* observed when magnified to the 400th power, and produced from the water decoction of amazonite from Miask changed by hydrofluoric gas.

Fig. 3. Silicic fluoride of *lithium*, magnified to the 200th power, and produced from the preparation of Prof. Stolba, by recrystallization upon the object-glass.

Fig. 4. Silicic fluoride of *sodium* (∞ *P*. *P*, ∞ *P*. 0 *P*.), magnified to the 400th power, and produced from the water decoction of albite from Zell (in Zillerthal) changed by hydrofluoric gas.

Fig. 5. Silicic fluoride of *calcium* (∞ *P*. 0 *P*, sometimes ∞ *P*. 0 *P*. ∞ *P̆* ∞ etc.), seen as magnified to the 150th power, preparation of Prof. Stolba.

Fig. 6. Silicic fluoride of *calcium* magnified to the 200th power, and produced from the hot solution of the above mentioned preparation upon the object-glass.

Fig. 7. Short, hexagonal prisms terminated by truncated pyramids of silicic fluoride of *sodium* and slender branching forms or spindle-like forms of silicic fluoride of *calcium*, magnified 200 times, and produced by recrystallization of a mixture of two parts by weight of silicic fluoride of sodium and one part by weight of silicic fluoride of calcium.

Fig. 8. Long hexagonal prisms terminated by blunt pyramids of silicic fluoride of *sodium* and thick, branching, or spindle-like forms of silicic fluoride of *calcium*, seen as magnified to the 200th power and prepared by recrystallization of a mixture of one part by weight of silicic fluoride of sodium and two parts by weight of silicic fluoride of calcium.

Fig. 9. Silicic fluoride of *strontium*, observed when magnified to the 200th power, and produced from the preparation of Prof. Stolba by recrystallization upon an object-glass.

Fig. 10. Silicic fluoride of *magnesium* (for the most part *R*, *R*. 0 *R*), magnified to the 600th power and prepared from chondrodite—through the successive treatments of the latter with hydro-fluoric gas and hydrofluosilicic acid.

Fig. 11. Silicic fluoride of *magnesium* (for the most part ∞ *P*2.*R*, *R*, in part imperfectly formed) magnified to the 400th power and prepared from humite by treatment with hydrofluosilicic acid.

Fig. 12. Silicic fluoride of *magnesium* (for the most part imperfectly formed and regularly grouped crystals,) magnified to the 400th power and prepared by treatment of magnesite with hydrofluosilicic acid.

Fig 13. Rare crystals prepared from some calcareous silicates (corsite, tankite), by successive treatments with hydrofluoric gas and hot hydrofluosilicic acid, and observed when magnified to the 400th power. It is yet to be proven to which metal they belong. (The pyramidal crystals sometimes irregular at the middle edge, as well as the rhomboidal forms belong most probably to calcium).

Fig. 14. Tiny, short needles of silicic fluoride of *barium* and shrubby but yet delicate forms of silicic fluoride of calcium, brought out only by breathing upon them, (these forms are strongly stamped in the figure), observed when magnified to the 400th power and produced from a calcareous witherite—by treatment with hydrofluosilicic acid.

Fig. 15. Silicic fluoride of *iron* (mostly ∞*P*2. *R*), magnified to 400th power and obtained from the silicic fluoride of iron preparation by recrystallization upon the object-glass.

Fig. 16. A thin section of *amazonite* from Miask which was covered with a drop of hydrofluo-silicic acid[1] and after drying of the drop observed when magnified to the 400th power. The cubes of silicicfluoride of potassium and the lattice structure of the amazonite are noticeable.

Fig. 17. Portion of a polished section of *oligoclase* from Ytterby, which was covered with a drop of hydrofluosilicic acid and after drying of the drop observed, magnified to the 400th power. Tiny six sided tablets of silicicfluoride of sodium, and thin spindle-like forms of silicicfluoride of calcium are noticeable.

Fig. 18. Portion of a polished section of *labradorite*, of changeable colors, probably near a *calcareously rich andesine*, the labradorite being from Ojamo in Finnland, was covered with a drop of hydrofluosilicic acid and

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[1] For all the specimens here mentioned the hydrofluo silicic acid was about 3½ per cent. strong.

observed after drying of the drop, magnified to the 400th power. Short hexagonal prisms usually surrounded by a bubble of air, of silicicfluoride of sodium and tablet-shaped, rhomboidal and thorn-shaped forms of silicicfluoride of calcium are noticeable.

Fig. 19. A part of a thin section of *labradorite* coming from the gabbro of Wolpersdorf, which was covered with a drop of hydrofluosilicic acid and observed after drying of the drop, magnified to the 400th power. The same crystal forms as in Fig. 18 are noticeable; but the spindle-shaped crystals of silicicfluoride of calcium are more numerous.

Fig. 20. A thin section of *anorthite* from the corsite from Corsica, which was covered with a drop of hydrofluosilicic acid and after drying of the drop observed, magnified to the 400th power. The same crystal forms as in Fig. 18 and 19 are noticeable; but the silicicfluorides of calcium are most numerous and the silicicfluoride of sodium most rare.

Explanation of Plate II.

Fig. 1. A cleavage fragment of *albite* from Dauphiné, which was covered with a drop of hydrofluosilicic acid and observed after the drying of the drop when magnified to 400th power. Short hexagonal prisms of silicic fluoride of sodium and wedge-shaped etchings sometimes arranged in rows were noticed.

Fig. 2. Part of a polished thin section of *leucite* from Vesuvius, which was covered with a drop of hydrofluosilicic acid and observed, after drying of the drop, magnified to the 400th power. Many cubes of silicic fluoride of potassium, two hexagons of silicic fluoride of sodium and a thin rod of silicic fluoride of calcium were noticeable, besides the polygonally etched and creviced surface of the section.

Fig. 3. Part of a polished thin section of *elaeolite* from Laurwig, in Norway, which was covered with a drop of hydrofluosilicic acid and after drying of the drop observed when magnified to the 400th power. Hexagonal crystals of silicic fluoride of sodium, a cube (in the centre of the illustration) of silicic fluoride of potassium are noticeable, and also the coherent plate, divided only by coarse veinlets of segregated silica through which the texture of the elaeolite with its delicate parallel groovings and its crossed cleavage cracks appears.

Fig. 4. A thin section of *scapolite* from Malajo, in Wermland, which was covered with a drop of hydrofluosilicic acid and observed after the drying of the drop, magnified to the 400th power. The spindle-shaped crystal forms of silicic fluoride of calcium, hexagonal tablets, often enclosed in a bubble of air, of silicic fluoride of sodium, parallel cleavage crevices, and between the latter wrinkle-like etchings are observable.

Fig. 5. *Left half. Lithium iron mica* from Zinnwald which was covered with a drop of hydrofluosilicic acid and observed after drying of the drop, magnified 400 times. Many crystals similar to a very blunt six-sided pyramid, of silicic fluoride of lithium, a crystal in the centre of the figure, of silicic fluoride of iron, a few cubes of silicic fluoride of potassium and a single spindle-shaped crystal of silicic fluoride of calcium.

Right half. Potassium mica from Greenland, which, treated like the mica mentioned above, shows besides two hexagonal prisms of silicic fluoride of sodium and two crystals of silicic fluoride of iron, only crystals of silicic fluoride of potassium.

Fig. 6. A dark-green *biotite* which was treated in a manner analogous to that of the micas given above and observed when magnified to the 400th power: showed larger crystals and slender prisms of silicic fluoride of magnesium and silicic fluoride of iron next to little cubes of silicic fluoride of potassium.

Fig. 7. A thin section of *amphibole* from Luhov (near Milleschase) which was covered with a drop of hydrofluosilicic acid and observed, after the drying of the drop, when magnified to the 400th power. Larger crystals and slender prisms of silicic fluoride of magnesium and silicic fluoride of iron, two spindle-like crystals of silicic fluoride of calcium, a cube of silicic fluoride of potassium, a hexagon of silicic fluoride of sodium and parallel, slender, wrinkled etchings are noticeable.

Fig. 8. A thin section of *diallage* from the gabbro from Wolpersdorf, which was covered with a drop of hydrofluosilicic acid and after the drying of the drop, observed magnified to the 400th power. Numerous spindle-shaped crystals of silicicfluoride of calcium, larger crystals of silicicfluoride of magnesium and of iron and systems of parallel cleavage crevices running out in three directions are noticeable.

Fig. 9. Fragments of *bronzite* from Graubat in Steiermark, which were covered with a drop of hydrofluo silicic acid and after drying of the drop were examined when magnified to the 400th power. Large crystals of silicic fluoride of magnesium, and of silicic fluoride of iron, and the texture of the bronzite fragment with parallel groovings are noticeable.

Fig. 10. A thin section of *dichroite* from Orrijärfvi, in Finnland, which was covered with a drop of hydrofluosilicic acid, and after the drying of the drop examined. magnified to the 400th power Larger crystals of silicicfluoride of magnesium and irregularly arranged wrinkled etchings are noticeable.

Fig. 11. A thin section of a grain of *olivine* from Kozakov, treated in the same manner as is explained under Fig. 2, but delineated in all parts as magnified to the 400th power.

Fig. 12. A thin section of *olivine* from Kozakov (at Turnau) which was covered with a drop of hydrofluosilicic acid and observed when magnified from the 200th to the 800th power. The silicic fluoride crystals of magnesium and iron (drawn when magnified to the 200th power) the prominent pyramidal wholly parallel subindividual crystals, which appear magnified from 600 to 800 times, and the rhomboidal etchings of the entire surface of the sections are noticeable.

Fig. 13. The middle portion of a *chiastolite* crystal cut almost perpendicular to the main axis, treated with fluosilicic acid and examined, magnified from 200 to 400 times. Besides the central kernel with its rhomboidal outline the dark gray cross and the feather-like branchings of the coal-like substance parallel to the lateral edges of the prism, one notices only a few colorless particles of the unchanged chiastolite, while the greater part of the upper surface of the thin section presents a spotted or delicate undulatingly fibrous structure which in some places along the edge changes into net-like aggregates of parallel bars.

Fig. 14. Etchings upon *lithia iron mica* from Zinnwald, produced by the action of hydrofluoric gas and subsequent boiling away in water, and represented as magnified to the 400th power.

Fig. 15. A thin section of *elæolite* from Laurwig in Norway, treated with chlorine gas and observed, magnified to the 400th power. Cubes of of chloride of sodium which remain sticking in the remnant of gelatinous silica (not removed from the surface of the thin section), also the prism-shaped or long wrinkled etchings parallel to the main axis of the crystals and two large cleavage clefts running perpendicular to the main axis are noticeable.

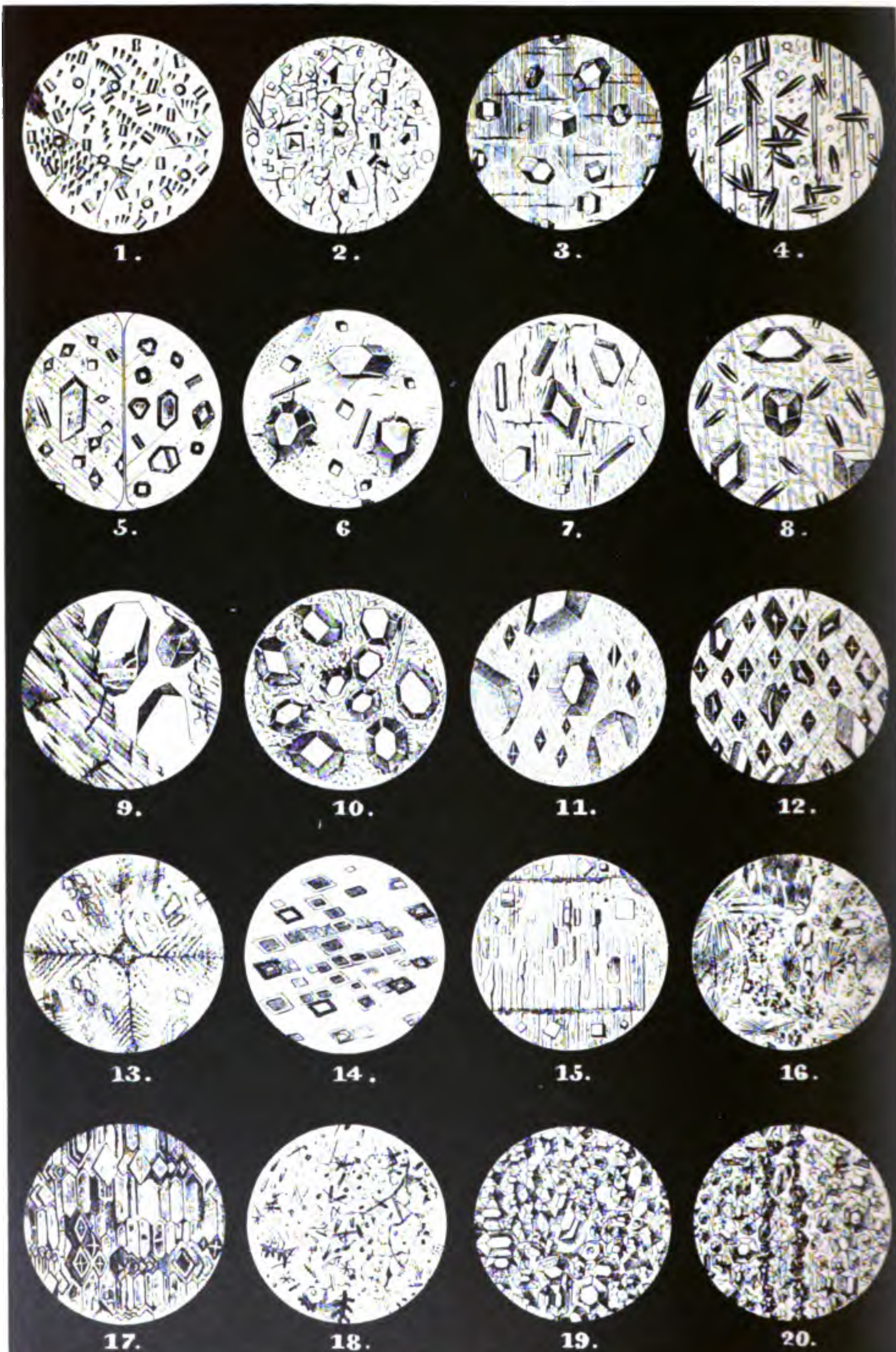
Fig. 16. A thin section of *apatite* from Schlackenwald which was cut parallel to the base, covered with a drop of hydrofluosilicic acid and observed, after the drying of the drop, magnified to the 600th power. Striated aggregates of prismatic and acicular crystals are noticeable as well as uniform, dark particles of silicicfluoride of calcium, sometimes displaying an oblique angled cleavage and distinct hexagonal subindividuals of apatite (P. 0P.), which sometimes display a beautiful scale-structure and are parallel or a little inclined to the main axis of the crystals. After successive boilings in water, by which the silicicfluoride of calcium is removed, the subindividual crystals of apatite appear most clearly.

Fig. 17. A thin section of *apatite* from Zinnwald, cut parallel to the prism surface, boiled about 20 seconds in aqua regia and observed when magnified to the 600th power. Rhomboidal etchings of various lengths and solitary, prominent lateral edges of subindividual pyramid crystals.

Fig. 18. A thin section of *apatite* from Schlackenwald which was cut parallel to the base, treated with chlorine gas, covered with Canada balsam, furnished with a cover-glass and observed when magnified to the 400th power. Short, dark microlitic needles which cross each other in a horizontal position usually at an angle of about 60° and are probably to be regarded as edges remaining of subindividual crystals, of the uppermost stratum, furnished with long adherent bubbles of air. Among these, faint lateral outlines of the subindividual pyramid-crystals of the next lower stratum are visible.

Figs. 19 and 20. Thin sections of *apatite* from Schlachenwald, cut parallel to the base, treated with chlorine-gas, directly covered, not with Canada balsam, but with the cover glass, and observed when magnified to the 400th power. Both pictures illustrate the structure of the apatite crystal from little, hexagonal pyramid crystals (P, P. $0P$), crowded closely together, sticking to each other, and almost parallel to the main axis. Upon those places of the apatite thin sections, which show no scale structure, the subindividual crystals are large and like thick tablets on account of the preponderance of the basal surfaces (Fig. 19). In the narrow scale zones, on the contrary, they are small and usually run out into pyramidal points. And the boundary lines of the scale zones consist of most extremely minute pyramidal crystals which are tolerably rectilinear and closely crowded together, as is shown by the two dark rows of crystals (boundary lines of the scale zones) of Fig. 20.

BORICKY'S MICRO-CHEMICAL METHOD.



BORICKY'S MICRO-CHEMICAL METHOD.

GEOGNOSTIC AND GEOGRAPHICAL OBSERVATIONS IN THE STATE OF MINNESOTA.

GEOGNOSTIC AND GEOGRAPHIC OBSERVATIONS IN THE STATE OF MINNESOTA.

BY DR. J. H. KLOOS.

[Extracted from the the *Zeitschrift der Gesellschaft für Erd kunde zu Berlin*. Bd. XII. 1877. Translated by N. H. Winchell].

[NOTE: In two former reports, the tenth and eleventh, have been given translations of a part of the work of Mr. Kloos, based on observations and collections made by him in Minnesota before the beginning of the present survey. The following paper is not given entire, but only such additional facts and discussions as are not found in the former papers. In this connection attention may be called to the more correct description of the "Silurian" strata at St. Paul, the record of a well driven at the Northern Pacific crossing of the Red River of the North, at Moorhead, the petrographical notes on the crystalline rocks, and on the slates at Thompson, and the paleontological remarks on the Lingulæ at St. Croix Falls.

Mr. Kloos, in a communication to the translator, dated Stuttgart, Württemberg, Sep. 13, 1885, criticises the translation of his remarks on *Owen's Report of a Geological Survey of Wisconsin, etc.*, (Tenth report, p. 175), viz: "You have remarked that I said, 'a fault of the work is its petty simplicity,' which, as it seems to me, is not quite the meaning of 'Ein Mangel des Werkes ist seine geringe Uebersichtlichkeit.' Petty simplicity means, in the German language, *Kleinliche Einfältigkeit*, which is not rather flattering for an author, and which not at all expresses my opinion of Owen's work. On the contrary this work was very valuable, and almost grand, considering the time it was written, but it contains too much, and the geology is wrapped up in so many detailed topographical descriptions that it becomes difficult for a geologist of modern times to find his way through the long pages.

"I allow that it is very difficult to give the exact meaning of 'geringe Uebersichtlichkeit,' and I am only able to translate it at some greater length, for instance: 'A fault of the work is its arrangement, which makes it rather difficult to acquire a general view of its contents.' I would be pleased if in a future publication you could find an opportunity to say something on this subject, as I am afraid that the American geologists have felt hurt in reading my opinion of Owen's work." The translator is very glad of the opportunity to correct, on the authority of the author, such an error in the former translation, as it involves the opinion held by one geologist of the work of another.]

THE RED RIVER OF THE NORTH.

* * * There are present all the indications that the Red river of the North, at some earlier time, yet geologically not very far distant, has had a southerly course, and emptied into the Mississippi through the Bois des Sioux river, lake Traverse, Big-Stone lake and the Minnesota or St. Peter river. The small space of land between these two lakes last named, from which the water runs in opposite directions, is entirely flat, and rises but little above the shore of either lake. It happens frequently in spring, when the mouth of the Nelson river, in the far north, is stopped by accumulations of ice, that this strip of land, as well as a large tract of the prairie along the western border of the state, is overflowed, and that then is formed one extensive lake,—so much so that a flat-bottomed steamboat was got across the flooded water-shed, from the St. Peter river into the Red river of the North.*

For an explanation of the above-mentioned change in the direction of a part of the gathered waters of western Minnesota, it is only necessary to suppose a slight elevation of the land to the north, or which is more likely, that since the glacial epoch a sinking of a few feet has taken place.

Corroborative of this hypothesis, reference may be made also to all the rivers and creeks in the northern part of Minnesota, which, coming from the north, turn at a sharp angle toward the west and empty into the Red river of the North, having rapid and impetuous courses; while the Bois des Sioux river, with a northerly course, is a very slow flowing stream. The Red river itself also flows slow, and numberless are the curves and angles which both these rivers describe. It is only necessary here to introduce a slight change in order to give the waters of this very level prairie an exactly opposite course.

THE DRIFT IN MINNESOTA.

* * * The drift deposits through all their great extent, in their totality, remain tolerably uniform. This is specially the case with the preponderating clayey portions, which everywhere lie directly on the older formations, occupying the lowest part of the diluvium. It exhibits, in this respect, a certain analogy to the drift-clay and marl of Germany (in upper Schleswig, Pommerania, &c). These clayey parts are not always present, but the sand and gerölle, which in normal order

*This probably refers to the attempt of Capt. Davis, in 1859, which was not quite successful.—N. H. W.

overlie the clay, are still more frequently wanting. The clay, on the other hand, often reaches a thickness of 100 to 120 feet, and in its lower parts generally is of a bluish color, though of a yellowish or brown color in the region of lake Superior, and nowhere contains organic remains, although very often small rounded pieces of limestone and fragments of slate.

I found everywhere in the western part of the state, in the calcareous clays which there constitute the basis of the prairie, little rounded white limestone fragments. If these be broken they show within the structure of a pure dolomitic limestone of a yellowish brown color. Only rarely does one see small rounded fragments of granitic rock, while the limestone pieces always far predominate.

The clayey portions, (by the inhabitants called 'hardpan' on account of their firmness and hardness,) form the sub-soil throughout the prairies and the woodland, as well as the gently undulating well-watered table-lands; while the accumulations of sand and gravel form a very distinct terrane with many isolated rather high ridges. The gerölle of this latter formation exhibits a great diversity, and besides Silurian limestone in more local accumulations, consists of the crystalline rocks and slates which in the far north are found outcropping at the surface. In the sandy, very hilly tracts, are also found many large erratic blocks, which are wanting upon the prairies, though they are found in great numbers about the fresh water lakes which occupy the depressions in the sandy and stony diluvium.

Concerning the origin of this clayey deposit, with no trace of organic life, as yet no established theory has been accepted, it is very generally considered to be the material transported by glaciers, including with it the sand, quartz and gravel which is spread over it. But in what way the process was carried on, by which the fine clayey parts were separated from the granular and siliceous, is not entirely understood. In the clayey diluvium, furthermore, are those lakes the water of which has a bitter salt taste, and is unfit to drink. These are in the western part of the state, but restricted to the characteristically prairie portions. Here, and specially north from the St. Peter river, the surface of the earth is rich in salts, and for miles can be seen a white, bitter-tasting salt-crust. forming the surface, while all wells, even to a considerable depth, give bad water.*

*This bad water was largely due to the use of pine planks for curbing, the pitch in which was acted upon by the alkaline salts in the waters, and has been greatly modified since the use of pine for curbing has been abandoned.—N. H. W., Compare the Sixth Annual Report.

The above-described light colored diluvial clay with small limestone gravel, which forms the subsoil of the wide prairies on the Red river, possesses, in the interior of the American continent, a great extension. It is apparently identical with the yellow marl, or "bluff formation," which F. V. Hayden describes in his work on the geology of the upper Missouri, and which in several places has afforded the bones of the mastodon and elephant as well as land and fresh-water shells.

The extensive and thick beds of clay which cover the Huronian and the lower Silurian rocks about lake Superior, are by some geologists considered as of the same age as the above diluvial clay of the northwestern states; for example, Winchell in his geological reports. Others, however, ascribe to the light colored non-laminated clay, (the true "hardpan") containing small gravel a later date than to the dark-red clays about lake Superior, which more frequently show a bedded structure.* I have not been able to learn of any direct superposition of one over the other.

The lake Superior diluvium differs from "hardpan," by its very marked deep red color, and a greater thickness. I have seen on the lower course of the St. Louis river, a section of this clay amounting to 500 feet. It seems also to be completely free from stones, but exhibits often a plainly bedded structure, and changes often to sandy and gravelly beds.

The diluvium in southern Minnesota has a great thickness. Along the boundary of Iowa the Silurian limestone is covered only by a few feet of sandy beds, and even seems to afford a region where the drift is wanting entirely, without exhibiting any of the characteristics of its southern boundary, which are to be found much more evident in the neighborhood of the Ohio river.

Yet in the central part of the state, by means of wells, the great thickness of this post-tertiary deposit is known. From a well which was drilled a few years ago on the Northern Pacific railroad where it crosses the Red river, I obtained the following record of the layers passed through:

3 feet (English), black earth.

92 feet clay (marl?) evidently colored, with a few limestone pebbles.

10 feet gravel.

115 feet hardpan, firm clay mixed with coarse gravel.

30 feet white clay beds.

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* Whittlesey on the fresh-water glacial drift of the northwestern states.

12 feet red coarse sandstone (looks like the Potsdam sandstone).

The river itself here has cut only to the depth of forty-five feet into the surface of the earth, and the shores attain nowhere a very much greater hight. It is hence questionable whether the whole thickness of 260 feet, of this section, belongs to the post-tertiary formation; rather I should be inclined to assign the deeper portion of it, and specially the 30 feet of clay-beds, to the Cretaceous formation, of the appearance of which at points not very far removed from this place, there will be a special description later. * * * *

THE LOWER SILURIAN ON THE UPPER MISSISSIPPI.

* * * * * * * * *

I shall have opportunity later to return to the lower sandstone, in giving a special description of the beds on the St. Croix river. Owen has called it the "lower Silurian sandstone of the upper Mississippi," distinguishing the dolomite as "lower magnesian limestone." The characteristic fossils of the sandstone are trilobites, belonging to the genera *Dikelocephalus* and *Conocephalus*, also bivalves, *Lingula* and *Obolus*, which in the vicinity of Taylor's Falls completely fill whole layers. In the crumbling sandstones of Minnesota it is difficult to find determinable fragments of trilobites. Relying on observations in Wisconsin, Owen distinguishes six trilobite-layers, which are separated from each other by layers from ten to a hundred and fifty feet in thickness, of the existence of which, however, Hall, still later, expresses doubt. In the magnesian limestone, up to the present time, have been found only insignificant, scarcely recognizable traces of fossils. They are small *Lingulæ*, stony forms of univalves, which are the modified remains of *Euomphalus* and *Ophileta*, and fragments of trilobites similar to those in the sandstone. The geological horizon of the lower dolomite must therefore be reckoned to fall in the time between the Potsdam sandstone and the strata of the Trenton.

* * * * * * * * *

The city of St. Paul is, in general terms, built on two terraces, of which the lower consists of the St. Peter sandstone, which is covered and protected by limestone layers but a few feet thick. The upper terrace is formed by the upper part of the Trenton, and upon that lies the drift. A long-extended series of hills, composed of heavy drift, very largely made up of limestone fragments, surrounds the city on the north, the

west and the northwest, while toward the south and the south west the terraces descend abruptly. From the present river channel these are separated by a tract of low, principally overflowed land. The lower limestone layers which are often broken and removed from their original position, contain numerously the fossil *Strophomena alternata*, of Conrad. The valves of this large shell are, as in the Cincinnati limestone, chiefly accumulated in certain beds, and cover the surfaces of the layers in hundreds. These are the "*Producti*" which W. H. Keating, the geologist and historiographer of Long's expedition in 1823, mentions at Fort Snelling.

There are also in these lowest beds of the Trenton limestone. *Ctenodonta nasuta* Hall, agreeing with the figures in Dana's Geclogy of 1864 as well as in the geological report of Canada (in French) published in 1864, page 187, fig. 166; *Bellerophon bilobatus* Sow. (J. Hall in Palaeontology of N. Y., vol i, pl. 40, fig. 3), and a little crustacean, apparently *Leperditia fabulites*. Further up the river, at Minneapolis, I gathered from this same limestone,

Murchisonia bicincta Hall, Pal. N. Y., pl. 38, fig. 5.

Pleurotomaria lenticularis Conrad, N. Y., pl. 37, fig. 6.

Subulites elongata Conrad, N. Y., pl. 39, fig. 5, and Geol. Rep. of Canada, (French), 1864, p. 194, fig. 179.

Orthoceras juncium Hall.

Orthis tricenaria Conrad (also at St. Paul), Geol. Rep. of Canada, (French), 1864, p. 176, fig. 151.

Unfortunately the fossils that occur in the very hard rock appear only as casts, and I was obliged to undertake the examination with only such, excepting in the case of *Strophomena alternata*.

At the foot of the above-mentioned upper terrace, in the midst of the city, are the stone quarries which supply building material for St. Paul as well as for several other cities on the upper Mississippi. In these quarries the successive strata of the dolomitic limestone are disclosed to the depth of thirty or thirty-five feet. Here are firm horizontal layers of a bluish color, spotted here and there with darker, and appearing to be penetrated by evident calcite. Fossils are rare in this middle portion of the Trenton, with the exception of impressions of fucoids (*Buthotrephis*) which I saw on several of the layers. The impressions agree best with the figures of *Buthotrephis*(*Licrophycus*) Bill. *succulens* Owen, in Dana's Geology, and in Hall's Pal. of New York, vol i, pl. 22, fig. 2a. Several larger forms might

answer for *Palæophycus rugosas*; Owen thought these were too badly preserved to permit an exact determination. Besides these plant-remains I found, in my frequent visits to these quarries, only impressions of *Orthis tricenaria*, *Pleurotomaria* and a species of *Lingula*.

Above the blue limestone follow five or six feet of clayey and marly beds of a dirty-yellow color with many, though poorly preserved remains of fossils. *Strophomena* is again of frequent occurrence, as well as *Orthis tricenaria* and a species of *Murchisonia*. In color and composition these marly beds are hardly distinguishable from the lowest beds, which lie directly on the sandstone. The highest beds of the Trenton group appear in some of the bluffs of the streets in the higher parts of the city, lying directly under sixty to seventy feet of gravel and sand. These streets at the time of my residence there had been but little worked. These beds are very rich in organic remains, especially if the forms that are not very different could be known. Thin plates of dense crystalline limestone alternate with the marl beds which crumble down in the air, the latter being of a dirty-blue color. The entire slope was covered with disintegrated shale, in the midst of which were scattered thin limestone slabs of evident crystalline structure, which swarmed with beautiful coral-like bryozoa and small brachiopods. The most beautiful, most delicate forms of the palæozoic sea lie here in numberless specimens loose in the clay, or without any difficulty separable from the surface of the rock at the limestone quarries. Bryozoa, crinoid stems, head and tail shields of trilobites, with little Rhynchonellas, Terebratulas, Leptæna, Orthis and several gasteropods form the fauna.

The same fossils are found on the opposite bank of the Mississippi; only the bank is entirely wooded, and the higher beds are not exposed. But fossils can be gathered along the foot of the lower bank, where every rainstorm washes them down the numerous little gutters on the bluff. On both banks I have found the following named species common.

Stenopora (Chætetes) fibrosa Gold. spec.
Chætetes lycoperdon Say.

These bryozoa are represented as *Calamopora* in Goldfuss' *Petrefakta Germ*, plate 64, figs. 9 and 10. Hall, in Pal. N. Y. vol. i, plate 24, fig. 1, considers the branched form (*Ch. fibrosa*) and the hemispherical form (*Ch. lycoperdon*) as belonging to the same species, which opinion I can confirm by the specimens

gathered at St. Paul. The cell-structure in them is exactly the same, and transitions from both forms are quite common.

Petraia (*Streptelasma*) *corniculum* Hall, (Pal. N. Y. pl. 25, fig. 1).

Rhynchonella recurvirostra Hall, (Pal. N. Y. pl. 33, fig. 5).

Rhynchonella increbescens Hall, (*capax* Con., Pal. N. Y. pl. 33, fig. 13, a, b, c, d, p, r, s). Geol. Rep. of Canada, French, published in 1864, fig. 153.

This is the most common brachiopod in the upper strata. The very distended varieties of this species, which are so common at Cincinnati and other localities of the Trenton, I have not yet been able to find—nor *Orthis lynx*, their constant companion in Ohio.

Strophomena deltoidea Con., (Hall, Pal. N. Y. I. pl. 31, fig. 3).

Strophomena sericea Sow., (Hall, Pal. N. Y. pl. 31, B. 2).

Orthis testudinaria Dalm, (Geol. Rep. of Canada, French, published in 1864, p. 175, fig. 144).

Chonetes lata.

Schizocrinus nodosus Hall, (Pal. of N. Y. I, pl. 27). Stem joints in great numbers.

Leperditia, spec. ?

Ptilodictya, spec. ?

Calymene senaria Con. (blumenbachii).

Illænus. Asaphus and Phacops. Head and caudal shields. The remains of trilobites are comparatively rare; but there are present numerous specimens of *Calymena senaria*, though not nearly so many as at Cincinnati.

These fossils have all been collected by Logan from the Trenton beds in Canada, and by Hall from beds of the same age in New York. They are also well known, for the most part, from the Llandeilo flags of England.

Hall remarks that on the upper Mississippi and at the Falls of St. Anthony, the lower part of the Trenton group as it is developed in the eastern part of the United States, the Birdseye, Black River and the Trenton limestone proper, can also be distinguished.

So far as Minnesota is concerned, this must be wholly erroneous, and it would be difficult to distinguish in the upper magnesian limestone three parts that are palæontologically and petrographically distinct. The fossils taken together point to the level of the proper Trenton limestone, and some extend much higher in the Hudson River group, though they are not found in the lower beds in the eastern states. While the thickness of the Trenton group in New York is said to average about

300 feet, that of the limestone beds, with alternating sheets of shale, lying above the St. Peter sandstone, at different points in Minnesota, amounts only to 25 to 50 feet.

Of the Lower Silurian strata of the eastern states, only the Potsdam sandstone and the Trenton limestone have been identified on the upper Mississippi with certainty. The intervening formations, which in the east are predominatingly limy (Calciferous sandstone, Chazy, Birdseye and Black River limestone) are represented in Minnesota by the lower dolomitic limestone and the St. Peter sandstone, from the former of which, as yet, only doubtful remains of gasteropods and of trilobites have been obtained, while the sandstone is entirely destitute of fossils.

In the eastern part of St. Paul, the horizontal limestone beds are suddenly broken off, while the sandrock is entirely washed out. An interval extending up to the next range of bluff (Dayton's Bluff) about a quarter of a mile, is filled with immense heaps of debris. It is a mixture of sand and limestone *gerölle* which has been shattered and cut through by running water. On the other side of the Mississippi also the same formation is found extending out to the Silurian bluffs. To judge from the amount and the mixed nature of this gerölle, the waters from the upper plains adjoining the town must, in former times, have gathered tumultuously into this valley; and this extension to the further shore of the river certainly cannot be assigned to a date before the Mississippi had acquired its channel through the Silurian strata. Through the thickest part of this mass flow still two creeks, with a strong current, viz., Phalen's creek and Trout brook. Along the former passes the Lake Superior railroad, in order to reach the level of the surrounding country, while the St. Paul and Pacific road, coming from the west, found its only approach to the capital through the valley of Trout brook, and is compelled to describe a great curve in reaching its depot on the bank of the river. This is likewise the only route which the great Northern Pacific road had to take in order to connect with the lines to Chicago and New York, which, during the winter months, constitute its only means of communication with the east.

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THE ARCHÆAN FORMATION ON THE UPPER MISSISSIPPI.

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The massive crystalline rocks of the upper Mississippi and Sauk river show a great similarity in their composition. In the

first place are the syenitic granites(micaceous amphibole-granites*) which form sometimes long, rounded, gently ascending ridges, and sometimes low rock-crags. In these rocks a bluish-white translucent feldspar (orthoclase) is abundant, which lends to the rock a bluish color. The hornblende is of a dark-green color, and appears in irregularly outlined shapes. On the borders these are covered with mica scales, which sometimes surround the hornblendes, and sometimes stand out from them. The mica appears most generally not as an original ingredient. Quartz, in very small grains, is apparent everywhere. Plagioclase, also is not wanting. In short intervals, between the heavily wooded ranges of hills that contain these rocks, rocky knobs jut out in the swampy meadows, which consist of syenite. The feldspar is reddish orthoclase, with more hornblende Quartz and mica are sparingly present. The latter always stands in close association with the hornblende.

A very beautiful syenite granite forms the reef at the mouth of Sauk river, which here gives rise to the so-called Sauk rapids. It is a variegated rock in which sometimes a blue and sometimes a red color prevails. It contains everywhere two kinds of feldspar—besides red and blue orthoclase, a considerable quantity of greenish plagioclase showing evident striation; black hornblende, a little mica and quartz. The hornblende is sometimes in separate masses as large as a foot in diameter.

Three small parallel dykes of a dark, fine-grained rock pass perpendicular through the syenite, with sharp outlines, and also can be followed on the opposite shore. But here, singularly, the adjoining rock is not syenite but a very hard granite-porphyry with large crystals of feldspar, the relation of which to the syenite it was not possible further to discover. Under the loup the ground-mass of the dark dyke-rock resolves itself into a mixture of a feldspar and an augitic mineral. Very beautifully and finely striated feldspar-plates are distributed porphyritically. The microscopic and chemical examination of this rock has placed its relationship with the melaphyrs†.

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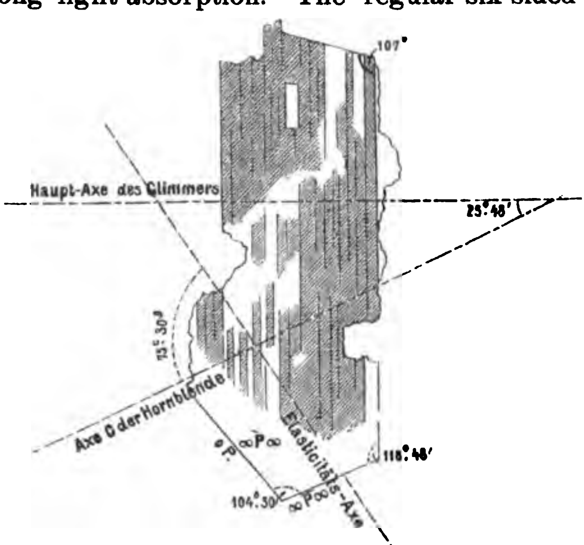
*H. Rosenbusch. *On granitic rocks*, in the *Zeitschrift d. d. Gesell*, XXVIII Bd., 2 Heft, S. 370 u. 371.

†In *Leonhard's Jahrbuch*, 1877, parts 1, 2 and 3, are set forth the complete microscopic and chemical characters of the massive crystalline rocks which I brought from Minnesota, whose investigation my esteemed teacher, Prof. Streng, of Giessen, had the goodness to undertake, some years ago; and in connection with the same are discussed the geological relations so far as it was possible to determine them, for which reason I here add nothing further on that subject. [See translation of this in the 11th report.—N. H. W].

Six miles further north, at the little town or Watab, (formerly a well-known point for trade with the Indians,) still another rock appears. The ridges here become higher and more conspicuous, but at the same time more heavily wooded and the rock outcrops less evident. The rock samples brought from Watab consist of quartz and augite dioryte along with syenite-granite and several varieties of hornblendless granite. Unfortunately the outcrops here are too few to make it possible to come to a conclusion as to the structural relations of these rocks with each other. On the spot one can only come to the conclusion that the granitic rocks outcrop as dykes in the quartz-dioryte, and that there is a greater extent of the latter than of the former.

A fine-grained rock from Watab, which is not treated of in the work in Leonhard's Jahrbuch, referred to on page 22, is abundantly pierced by blades of feldspar, and, even under the loup, shows much colorless feldspar and dull quartz along with a dark mineral (hornblende?) and a little tombac-brown mica, gave the following microscopic characters: In a clear groundmass, clouded only in spots here and there, lie the forms of green and brown crystals. Both are strongly pleochroic; the green become grass to yellowish-green, and show little absorption; the brown play from dark brown to light yellowish-brown, with strong light absorption. The regular six-sided sections



The faded portions indicate mica. The numbers and characters pertain to the hornblende.

of the latter mineral remain, at crossed Nicols, completely dark. The rectangular diagonal sections polarize brightly, and exhibit a lamellar structure. The green mineral has the cleavage of hornblende, the brown is mica. Hornblende and mica are often interchangeable, which appears here very evident by the difference of color.

Generally the mica lies about the margins of the hornblende, and surrounds it more or less regularly. In one case was to be seen a very beautiful interchange between hornblende and mica through a space of 0. 8 ^{mm} by 0. 3 ^{mm} as exhibited in the foregoing figure. By measuring the angles, and noting the position of the line of extension it was possible to determine that the principal axis of the mica forms an angle of about 23 degrees with axis C of the hornblende.

In polarized light the clear groundmass is resolved into individual grains of feldspar and quartz, the latter polarizing brightly and forming the cementing material between the feldspars. The latter are mostly twinned, sometimes clouded and sometimes not; some of them striated, others not. Often, of two or three individuals standing in the position of twins, one shows a striation and the others polarize singly or as units. Orthoclase is decidedly predominant. Quartz and orthoclase are filled with long needle-shaped microlites which are altogether colorless and pellucid, and have the aspect of apatite These needles, whose abundance is remarkable, penetrate also the hornblende and the mica. They show, under higher power of magnifying, evident polarization, are very often fractured, and for the most part are feebly bound together.

The rock is cut by feldspathic veins, which consist prevaililgly of clouded orthoclase although scattered plagioclase and irregular outlined grains of quartz also are visible. It is remarkable that here the apatite needles are wanting. Moreover the microscopic field furnished also some scattered minute reddish-brown clouded sections which are doubly refracting and may be titanite. There is a sprinkling also of pyrite.

This rock is accordingly a very finegrained magnesia-mica amphibole-granite, with more hornblende than the other granitic rocks of the upper Mississippi possess.

At Watab there are also melaphyrs which may sustain the same relation to the syenite-granite as at Sauk Rapids. Only here the formation is difficult to investigate, and the heavy forest, which afforded only isolated exposed points for observation, made it impossible in the limited time which I could devote to this

point, to determine certainly a dyke like manner of outcrop, such as is plainly exposed at Sauk Rapids. The melaphyrs brought from Watab are very hard and compact, under the loup of an entirely felsitic aspect; and the microscope has already revealed in them a triclinic feldspar, a greenish, somewhat changed augite and magnetite.*

* * * * * * * * *

North from Watab the banks of the Mississippi, for a distance of twenty miles, furnish, again, no outcrop of rock. At the village of Little Falls, which is twenty-seven miles distant from the mouth of the Sauk river, the stream takes its way through a wide zone of mica schists and crystalline clay slates, which are developed to some extent as a good roofing-slate. The dip of the outcropping layers is toward the northwest, from 65° to 72° while the slates have a dip in the opposite direction from 70° to 80°.†

The rock overlying the schists consists of roofing-slates, that underlying is the mica schist next to be described. Between these lie micaceous clay-slates. Inasmuch as the schists which prevail from this place southwardly, on account of the fine distribution of the mica scales, have the aspect of a fine-grained gray gneiss, and it was of great importance, on account of its resemblance to another Archæan rock, to determine the presence or the absence of this kind of rock on the Mississippi, I had two slides made of the mica schist, one parallel with and the other perpendicular to the schistose structure. Under the microscope the predominant mica scales appear, in the former slide, in a colorless, pellucid groundmass, having six-sided outlines and a dark brown color. They remain dark at crossed Nicols; while the irregularly four-sided and the rectangular, long, diagonal sections exhibit a lighter color, a strong pleochroism and an evident lamellar arrangement. In the second slide the long, striated sections of the mica lie in a more or less parallel position, and between them are visible still a much greater number of wedge-shaped mica blades which, on account of their minuteness, appear colorless and do not afford any means of detecting any pleochroism. There are, however, also some blades which, parallel to 0P, remain dark at crossed Nicols.

In polarized light, and especially at crossed Nicols, the ground mass is resolved into clear, regular polyhedrons of

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*Eleventh annual report, page 50.—N. H. W.

†The dip of the slates is given by Owen (l. c. p. 166) as the dip of the formation. The bedding lines were nevertheless plainly to be seen, and were evident, furthermore, by parallel bands of milk white quartz.

quartz, those of the same size ranked together. The appearance is much like that of a mosaic, and it is very interesting that in this respect both slides perfectly exhibit this structure. Hence it is very plainly demonstratéd that the schistosity is dependent entirely on the position of the mica scales.

The quartz is relatively poor in cavities, though with a power 475 diameters I could distinguish some isolated fluid-cavities with moving bubbles.

Besides quartz and mica, the microscope brought to light in this schist only some grains of magnetite; of feldspar no trace can be distinguished, nor of apatite. The absence of feldspar shows that here we have to do with a genuine mica-schist, though this rock has formerly been conceived by me to be a gneiss, and has been so noticed.* The great roll which gneiss plays in the Archæan formation in America as well as in Europe, makes the absence of it on the upper Mississippi very remarkable, and warrants the opinion that it will still be found under the drift deposits.

In connection with this very evidently bedded mica-schist, at the place last mentioned, appear some diallage-diorytes, formerly described, which in the work referred to, were designated augite-diorytes.

South from the village the dioryte rises in the midst of the river-bluff, in low. broken cliffs, at the foot of which a stream has its entrance. Further up this stream also diorytes are again met with in the bed of the creek. These also contain diallage and are very fine-grained. The two places where these rocks outcrop are separated by low swampy ground, but are distant from each other only a few hundred paces, wherefore a continuation is probable without any intervening schist. Furthermore, in both these rocks, in hand-samples, it is possible to observe transitions in which the characteristic crystals of diallage appear surrounded by an outer band of hornblende.

Inter-stratified with the crystalline micaceous clay slates, are small lenticular masses of a granular hornblendic rock, which, both by its chemical and its microscopic characters, is found to be a quartz dioryte. These lie parallel to the schistose structure, which conforms to their contour, measure from a few inches to over two feet, and have, especially about their margins, great numbers of little garnets; while the inside is a cavity whose walls are often lined by quartz crystals.†

*See Leonhard's Jahrbuch, 1877, p. 36. *On the crystalline rocks of Minnesota in North America*, by A. Streng and J. H. Kloos. Also compare the Eleventh report, p. 34.—N.H.W.

†*On the crystalline rocks of Minnesota*, by A. Streng and J. H. Kloos. Leonhard's Jahrbuch, 1877, p. 36. Compare also the Eleventh annual report, p. 34.

North from Little Falls, the rocky strata disappear again under the sandy prairie; soon the river banks become completely wooded and afford nothing of geological interest. Rocky outcrops are first seen again at the falls of Pokegama, ninety miles further north. Here are beds of granular sandstone, or quartzyte, the age of which has not yet been determined.

THE CRYSTALLINE ROCKS OF THE SAUK VALLEY.

The Sauk river, which has already often been mentioned, cuts from east to west through the belt of crystalline rocks, of which we have already ascertained the foregoing facts, and and which outcrop at its mouth. Westward from the Mississippi, the first rock-exposure is at a distance of three and a half miles. Here are again low knobs of a red granite, having magnesia-mica and amphibole. Thence for twenty-five miles are long ridges of granitic rocks, heavily wooded. The intervening valleys are filled with drift, which has given origin to a series of ridges that rise from the sandy prairie. The most favorable exposures are at the villages of Rockville, where a very coarse-grained granite has wide extent, and Cold Spring, where in company with this is found a fine-grained porphyritic variety. The coarse-grained granite, different from any outcropping on the Mississippi, constitutes the prevailing rock at Richmond, where it is seen not to cease but to extend over the surrounding country, outcropping in the creeks and through a coarse debris which consists of orthoclase crystals, fragments of quartz and disintegrated mica. At Richmond is found again a dark, fine-grained augite-dioryte, of which the chemical composition, microscopic characters and relative position in the rocks have already been published in the work referred to.*

These rocks cannot be followed further west than Richmond. This village is situated at the border of the western prairies which the eye cannot span, where all geological investigations have to cease. Only at one point, near the village of Sauk Centre, forty-three miles west from the Mississippi, is there an upward swell or undulation, of the rock through the covering of earth. Here is a low ridge of crystalline rocks. A little quarry, opened by the German farmers for the purpose of getting stone for the foundations of their houses, has disclosed two different rocks; one a granite which for the first time exhibits a somewhat gneissic structure, and the other a quartz-dioryte. The

*Leonhard's Jahrbuch, 1877, p. 37 and 118; also, see my paper in Silliman's Journal, 1872, pp. 18-20.

whole outcrop is only sixty to seventy feet wide, and disappears in all directions under the grassy plain.

There is no doubt that the crystalline rocks of the Mississippi and the Sauk river belong to the Laurentian formation, and that the above described outcrops form only isolated points of observation in a wide belt of that formation which passes through Minnesota from north to south. The connection with the more extensive outcrops of Laurentian rocks in the northern part of the state is, nevertheless, as yet, only conjecture, and so it will remain, indeed, for a long time to come. Whether the crystalline schists at Little Falls should in like manner be placed in the Laurentian, or be considered to represent the Huronian, must likewise remain at present undecided. From the Laurentian rocks, as they are developed in Canada and Michigan, north and south of the great lake, those on the Mississippi differ notably in the lack of gneiss and crystalline limestone, although the presence of the latter in that region is indicated by great rolled fragments which I met with, particularly north of the Sauk river. With the Huronian also, as those rocks are described on the north shore of lake Huron, the schist-complex at Little Falls does not agree, inasmuch as the great conglomerates are wanting which are described by the geological reports of Canada.* The Huronian in the western part of Minnesota also is different, as we shall see below, and resembles more the beds of that age in Wisconsin and Michigan.

In a southerly direction the Laurentian zone is again met with on the St. Peter river, seventy miles distant. Owen describes from there, between the mouth of the Cottonwood river and the Redwood, granite and syenitic rocks extending over forty-five miles. These have been described more recently by N. H. Winchell in his second report. At several places they appear to take on a gneissic structure, and to pass into hornblendic schist.** The resemblance of the granite to that at St. Cloud he calls attention at several places. In the vicinity of Granite Falls and Patterson's rapids, on the St. Peter river, the granite is cut by dykes of trap and greenstone which can be followed for a distance of half a mile.†

* In the reports for 1864 of the Canadian geological commission, at the base of the Huronian system on the Thessalon river, north of lake Huron, are mentioned chloritic schists which alternate with diorytes, and therein appear to present a greater analogy with the appearances on the Mississippi.

** Prof. James Hall also has mentioned the gneissic character of these rocks.

† Second annual report on the geological and natural history survey of Minnesota. p. 160, et sequens.

The region between the Sauk and St. Peter rivers affords no outcrops. It consists sometimes of thick forest and sometimes of rolling prairie, and has a wonderful number of lakes. The connection of the crystalline rocks north and south is, nevertheless, probable, if one bears in mind the general relations of the terrane. While the first plateau along the Mississippi, west from the supposed belt of Laurentian rocks, has an absolute hight above the ocean from 750 to 800 feet, and in the west the prairies of the Red river lie at an average elevation of 850 feet, the elevation over the sea of the table lands in the strike of the granite belt reaches 1,100 to 1,250 feet according to the levels of the engineers of the St. Paul and Pacific railroad.

Whittlesey and Norwood, assistants of Owen, more especially entrusted by him with the examination of the interior of Minnesota, have likewise assumed a belt of crystalline rocks which goes diagonally through Minnesota and is crossed by the Mississippi as well as by some of its tributaries. In this, Winchell also concurs, and has exhibited on his very hypothetical map a wide zone of granitic and metamorphic rocks in immediate connection with those in the northern part of the state.

So far as our present knowledge of the geological nature of the interior part of Minnesota extends, it can only be said of it that there are present all indications of the existence of an area of Laurentian rock, but that it appears in outcrop only in the shores of the larger streams, and is covered by a very heavy deposit of drift over almost its whole extent, and is thereby hid from geological examination. Also concerning the Huronian it is only permitted to presume as yet its existence on each side of the massive crystalline rocks. As the schists at Little Falls, on one side, can be so regarded, so Prof. James Hall classes the metamorphic sandstone and red quartzyte in southwestern Minnesota, which have there a great development, and also embrace the pipestone or catlinite layers, as equivalent to the Huronian in the neighborhood of lake Superior.

Equally valid also are all the Silurian boundaries which (as well as Devonian strata) Winchell represents on his map* in beautiful order west of the granitic and metamorphic zone. As Winchell himself remarks,** this supposition rests entirely

*This map appears as a "preliminary geological map of Minnesota," with his first report.

** Pages 94 and 109, of the first report.

and only on the fact that Prof. Hind, of the Canadian geological commission has exhibited on his map of the British possessions, north from Minnesota, similar portions of the Silurian and Devonian in belts running from north to south along the Red river, and that these extend to the 49th parallel of latitude, the boundary line of the United States.*

But they are ideal there also, inasmuch as the southern part of the Winnipeg district is covered, like the northwest part of Minnesota, by a heavy sheet of drift below which the deepest wells penetrate only into the clay shales of the Cretaceous formation. So far as I know, there is no instance of outcropping old rock along the Red river throughout its course in the United States, and the same is true of its course for sixty miles further northwest. It is true Owen mentions that he found an outcrop of limestone with Silurian fossils two to three feet above the level of the water, on the upper course of the Red river. I have, nevertheless, sought for this place in vain, and am strongly inclined to believe that the American geologist mistook a limestone boulder with fossils of the Trenton formation for outcropping rock *in situ*. The existence of a great thickness of transported drift in this region (an out-running portion of the Leaf Hills, which will be mentioned below,) makes this the more probable.† Should later investigations establish the correctness of Owen's statement, there would be reached then a long stopping-place in the progress of our knowledge concerning the structure of the earth's crust in this difficult portion of North America.

THE CRETACEOUS FORMATION IN THE SAUK VALLEY.

At the village of Richmond on the Sauk river where the granitic and dioritic rocks of the Laurentian zone disappear entirely under the drift deposits, the river has cut a valley into the prairie the depth of thirty feet. In the steep banks I found strata of rock such that I had not as yet encountered in Minnesota, and which caused me to infer that I had here to do with strata of a younger formation. They are plastic clays of a prevailingly dark-blue color, with isolated lines of what appears to be white and yellow. Below the dark clays is a layer of kaolin

*The report of Professor Hind on the Assiniboine and Saskatchewan district of British America appeared in 1849.

†This statement of Owen is on page 173 of his *Report of a geological survey*, etc. According to his description this spot lies 50 miles distant from Otter Tail lake, measured by the river, and hence ten to twelve miles above Breckenridge, the end of the St. Paul and Pacific railroad. On his map this place is given at least fifteen miles further up the river.

with fragments of rock broken from the granite, and a few feet above the kaolin can be seen a band of very impure brown coal. The beds lie about horizontal, except that the kaolin layer has an entirely irregular outline, and presents to the beholder the appearance of a cloak-like covering of the underlying rock, which everywhere is granite as this appears in outcrop a short distance away.*

The river bluffs afford only scanty indications of the age of this formation. In spite of eager and continued search the plastic clays afforded me, besides several small fragments of shells, only a single small tooth of *Corax* or *Galeus*, which cannot be considered very reliable in determining the age of the beds. A few steps from the point at which these were found, shortly before my arrival, a shaft had been sunk, and in it a drill-hole carried further in hope of finding coal, which for several years has been reported in this region. By means of this mining work, though indifferently carried on, and by means of wells in the vicinity, have been discovered only some clay shales with impressions and fragments of fossils which show most conclusively that the beds which here lie directly on the granite belong to the Cretaceous formation, and indeed to the Benton group, or No. 2 of the series of the Missouri basin as it has been described by Meek and Hayden.** Not only are the bivalves, cephalopods, fish-teeth and scales identical, but the clays and shales are the same, at these distant points, and make it possible to establish an exact parallelism. Dark, plastic clays predominate. These alternate with fragile schists, with impure brown coal and clayey ironstone. The plasticity and the dark-blue to lead-gray color of these clays are so characteristic of the Benton group that they are distinguished easily from the sandy and marly portions as well as from the calcareous clayey beds of the upper members of the Missouri-Cretaceous.***

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*Winchell found later in several places on the St. Peter river, that a kaolin layer lies between the granite rocks and the clay beds, and sand deposits which here also are probably Cretaceous, (second annual report, 1874, p. 163, etc.) My observations upon the Cretaceous formation in Minnesota were first published in January, 1872, in Dana and Silliman's Journal of Science.

**Meek and Hayden's Palaeontological report of Lieutenant Warren's expedition to the Upper Missouri.

F. V. Hayden: On the Geology and Natural History of the Upper Missouri, in the Trans. Am. Phil. Soc., vol. xii, new series, part I.

***It is possible that the Fort Pierre group, only, could be confounded with it. This, however, holds a higher horizon, and likewise sometimes contains dark-colored plastic clays; but according to Meek and Hayden, the *Inoceramus problematicus* (= *In. labiatus* Schloth), the most abundant shell at Richmond, has not yet been afforded by these beds.

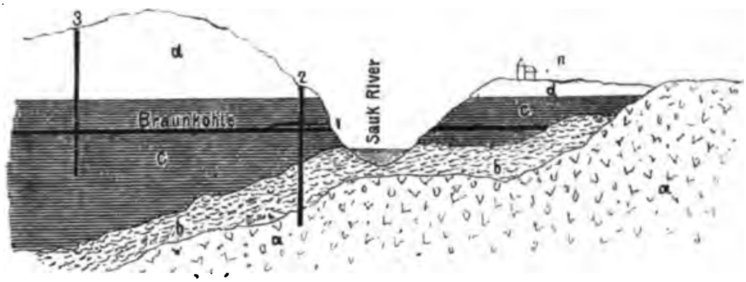
The above mentioned drill-hole, unfortunately, was made by men in whom all geological knowledge is wanting, and who neither kept a register of it nor were they in condition to give any reliable information concerning the nature of the layers penetrated. I was compelled, therefore, to depend on the material that had been piled up about the shaft.

The first search for coal was undertaken several years before by a farmer who had discovered the soft brown coal layer in the banks of the river. He ran a drift a distance of about sixty feet into the southerly bank, but a sudden rise of the water flooded his works and he then gave up the search.

The same farmer found coal three miles north from Richmond, in the midst of the forest, and dug three or four shafts in order to discover the supposed stratum. These also he was obliged to give up on account of the increasing waters. After that the matter remained unnoticed till 1870, when several merchants in St. Cloud rented the land in and around Richmond for the purpose of exploring for coal. There were sunk thereupon several shallow shafts in the neighborhood of the former experiment.

At the time of the experiment a streak of coal was said to have been followed of the thickness of four inches. The coal remained, nevertheless, very impure, and consisted, indeed, for the greater part of bituminous shale, which even now can be seen in the little mound thrown up near the opening of the pit. The dip amounted to four feet over the whole distance of sixty feet, and hence for the whole clay-complex a slightly inclined position was shown of about four degrees toward the south. At the opening of the shaft could be seen blue, white and yellow plastic clays with a little gravel and much clay shale. The shale contains here some scales of cycloid fishes as well as many fragments of *Inoceramus* and *Ostrea*, but unfortunately not a single entire specimen of any determinable species. The adjoining profile shows the appearance of the Cretaceous beds at Richmond.

It is worthy of note, still, that in an old pit in the neighborhood of the trial pit small quantities of a very clear petroleum had gathered, and that the water of a brook in the neighborhood carried with it some petroleum.



a. Granit,
b. Kaolin,

c.c. Plastic clay and clay shale with a thin layer of impure brown coal.

d.d. Diluvium.

1. The above mentioned small test drift.
2. Shaft and drill of a hundred and twelve feet in which the granite was reached. The drill-hole entered the granite eight feet, and the auger brought up small pieces of feldspar, quartz and pyrites, apparently derived from a pegmatite like the same that I have met with frequently as viens in the granitic rocks of the region.
3. Shaft and drill a hundred and eighty feet deep in which the granite was not reached.

Afterward having learned that in the digging of wells at several farm-houses south from Richmond, fossils had been discovered, I set out on a search in that direction. On the surface nothing more can be seen of the easily distinguishable clays and clay-shales. The land is very rough, heavily wooded, and the sandy drift in some places very significantly disappears. Two miles south from the village I came to a farm-house where a well had raised to a high pitch the wonder of the whole region about. The well was dug thirty feet deep, and then by means of boring had been carried ten feet still deeper. At eight feet below the natural surface of the ground a dark plastic clay was encountered, which gradually changed to clay-shale with numerous large shells. The water of this well smelled strongly of sulphuretted hydrogen, but the odor was lost after it stood a little time in the air, and it was then used as drinking water. At that time I could obtain at the place only small fragments of shells, from which the clay shale had crumbled, and the valves had been broken. Of the relation of

these fragments to *Inoceramus* but little doubt could be entertained. The well was soon afterward sunk somewhat deeper (always with the hope of encountering the coal stratum,) and the owner sent me several good specimens of the organic remains that were thus brought to light.

Besides the same fish-scales as on the Sauk river, were the valves of a large *Inoceramus* in great numbers, sometimes with the pearly interior perfectly preserved. Prof. Meek, at Washington, had the goodness to name these, and declared them to be the *Inoceramus problematicus* of the American geologists, adding further that this shell is identical with the *Inoceramus pseudomytiloëdes* which Dr. Schiel has figured in the second volume of the Pacific railroad reports, plate III, fig. 8.* I also got fragments and impressions of *Ammonites percarinatus*, Meek and Hayden, known from the Benton clays on the Missouri, very likely the same as *A. woolgari* Mant, and a *Scaphites* which Prof. Meek identified as his *Scaphites larvæformis*, or a closely related form of it, and which can scarcely be distinguished from *Scaphites æqualis* Sow.**

According to these fossils the clay and shale beds on the Sauk river correspond to the Lower Chalk, of England, the middle plains of Saxony, and the lower Turon of France (Turon Frankreichs).

According to the latest reports that have reached me, the well had been sunk, in a vain search for coal, still forty feet deeper, and that altogether it had reached the depth of 80 feet. The following statement shows the nature and thickness of the strata penetrated:

		Feet
1.	Gravel and sand	8
2.	Dark-blue, plastic clay, occasionally with a tendency to the form of shale; numerous valves of *Inoceramus problematicus* and crystals of gypsum	30
3.	Hard, sandy clay, and shale of lighter color, with pyrite, mica scales, and numerous scales of cycloid fishes. Fragments of *Inoceramus*. At the depth of forty feet a thin stratum of brown coal	8

*Probably this *Inoceramus* is identical with *Inoceramus mytiloëdes*, Mant. and *Inoc. labiatus*, Schloth. (Goldfuss, Petrefakta Germaniae, pl. II, p. 118. fig. 4.)

** At that time I sent the fossils and figures of the fragments which had crumbled. to the immortal professor Meek, at Washington, for determination. It has been impossible for me, however, to institute any later comparisons with European forms though the above determinations by so thorough a student of the Cretaceous formation of the interior of North America are sufficient to establish the horizon of the Minnesota beds and their full identity with the Fort Benton group on the Missouri.

4. The same clay with more layers of shale from three to four inches thick. Very large specimens of *Inoceramus problematicus*, as well as *Scaphites* and *Ammonites*. The valves sometimes retain their color and luster. At the depth of 50 feet a second thin bed of brown coal....	10
5. Dark blue plastic clay without layering; the color still darker than the last thirty feet above, and sometimes entirely black. At the depth of 65 feet it was necessary to bore through a hard bed of grayish-black color.......	15
6. Clay, with thin scales and layers of pyrites...........	10
Total..	81

The well was begun about 30 feet above the level of the water in Sauk river, and therefore at the same level as the prairie at Richmond, which shows the nearly level position of the strata. In a low meadow which in time of high water in the river, is connected with the river, I found the same unusual plastic clay at the surface. The locality where the above fossils were found lies two miles nearly south from Richmond, at the residence of a German farmer named Sieverding. The formation here certainly attains a very great thickness.

Besides the region about Richmond, I have also found the blue plastic clay on the shores of White Bear lake, in Pope county, [now Minnewashta lake—N. H. W.] at Glenwood, a village which lies 42 miles west from Richmond, and is 75 miles in a right line west from the Mississippi.* Here the clay appears under a covering of about two hundred feet of drift. This place is, therefore, the only positive evidence which I can cite for the extension of the Cretaceous beds towards the west, although I do not doubt such an extension, as will be further shown below; and hence, I believe it is correct to assume that these beds are continuous with the Missouri Cretaceous.

In the southern part of the state, Prof. Hall had ten years before described an impure, worthless bed of brown coal, which was associated with crumbling sandstone and sandy clays. In these beds appear leaves of dicotyledonous plants which point to an equivalence with the lower, or Dakota group, of the Missouri Cretaceous. They rest directly upon red-quartzytes which

*White Bear lake is one of the most beautiful lakes in Minnesota. The water-level lies about 150 feet below the level of the surrounding prairie. The shores are steep and as usual are covered with great boulders which are derived from the sandy drift. The blue plastic clays come to light at a spot, a few feet above the surface of the water, where a spring gushes out of the bank whose clear water must have been gathered between the yellowish sandy loam and the blue clay.

Hall, as above mentioned, assigns to the Huronian formation. From Nobles county, on the border of Iowa, some years ago several fragments of *Baculites* were brought to St. Paul and were preserved in the collection of the Natural History Society. They were alleged to have been found in beds of clay several feet below the surface. In late years, N. H. Winchell has accurately described* as Cretaceous, the beds that are to be seen along the lower course of the St. Peters river, in southern Minnesota. Unfortunately he has found no fossils, except a few remains of leaves, and, therefore, the age of the sands, clays and marl-beds which lie on the Silurian rocks can be announced, as yet, only as conjectural. Not to mention that without the aid of fossils it would be difficult to decide whether a portion of these younger beds be not diluvial, yet, on account of the frequent appearance of an impure brown-coal, it is possible to suggest for them a Tertiary age, and to conceive them as contemporary with the beds which have been described by Hayden and Meek as the Great Lignite formation of the Missouri. Therefore it must remain for later research to furnish more light on this point.

Although all these localities are three hundred miles distant from the Missouri, the natural surface of the intervening region (the eastern part of Dakota territory and of western Minnesota) affords no objection to the supposition that the above-described Cretaceous beds and perhaps the still later brown-coal and sand are connected with the Cretaceous and Tertiary formations of the Missouri. There is no exposure of older strata, in this latitude, between the belt of Laurention rocks in the interior of Minnesota and the above formations on the Missouri. The several low hill ranges, the Leaf hills in Minnesota, and the Coteaux des prairie in Dakota, are nothing but great accumulations of sandy and stony drift. The Leaf hills, a succession of long ridges curved like a horseshoe, situated between the Red river and the sources of the Mississippi, I have crossed myself in several places, for the purpose of finding a suitable route for a railroad to the British possessions. Nowhere, not even in the deepest cuts, were any outcropping rock beds seen.

The southern sides of the hills are very steep while to the north their slopes are very gradual. The strongly marked terrane is in width from six to ten miles and is composed of long parallel ridges joined by smaller transverse ones. Boulders of

*First and second reports on the geological and natural history survey, 1873, 1874.

various sizes of crystalline and sedimentary rocks lie scattered in wild confusion with numerous and very large erratic blocks.

Personally, I did not visit the Coteaux of Dakota but every opportunity was embraced of becoming acquainted with it through the engineers and surveyors. I was assured that at least between the 45th and 47th degree of latitude, here considered, there was seen no outcrop of sedimentary rocks of any kind either along the water-courses or on the hillsides. This region, like the Leaf hills, appears to be made up of unstratified stony and sandy material.

Under this supposition both of these elevated ranges are of later origin than the deposits of Cretaceous age and were not present at the time when the almost completed level upland formed the bottom of the Cretaceous sea. For this reason there is less need of admitting the existence of a number of small Cretaceous seas and particularly since the discovered fossils are absolutely identical. The various divisions of the Cretaceous formation along the Missouri show in their thickest development a thickness of nearly two thousand feet and it is therefore probable that during Cretaceous times a large ocean covered the interior of the North American continent.

On the maps included in the works of Hayden and Meek, the eastern boundary of the Missouri-Cretaceous sea is not given and professor Meek has assured me that this is totally unknown. The formation disappears towards the east under the great diluvial covering.

So far as I am acquainted nothing has heretofore been discovered of the eastern extension of the Missouri-Cretaceous sea. It seems to me from the above information and observation that the conclusion will be granted that the described strata of Sauk river near Richmond formed a portion of the eastern shore line of the Missouri-Cretaceous sea; however, I do not wish it to be understood that this correlation is established as a positive fact.

The Lower Silurian and the Huronian Melaphyr of the St. Croix Valley.

The same difficulties met with in geological explorations west of the Mississippi Valley are also met with along our route through the state east of this great river until we reach the valley of the St. Croix. This river has its origin in the vicinity of the western arm of lake Superior and flows southerly

towards the Mississippi and joins it after having formed the boundary line for 90 miles between the states of Minnesota and Wisconsin. In this entire distance the shores are covered with a dense primeval forest generally of pine, with a light sandy soil, while west of the Mississippi the forest is of deciduous trees and consists of oak, ash, maple, linden, walnut, etc., that grow in a heavy clayey soil. Only along the southern course of the St. Croix there extend sandy prairies interrupted by small forests of bur-oak to the vicinity of St. Paul.

Immediately after leaving the shores of the Mississippi on one side and the St. Croix on the other all possibility of geognostic observations on the surface are at an end. I have already stated that the first plateau of the Mississippi is from 750 to 800 feet above the ocean level. At this elevation the surface remains eastward from St. Paul to the St. Croix river. One rides for hours over rolling prairies and passes several large lakes in which the sandy and abundant diluvium with large erratic blocks cover all of the older sedimentary rocks. Suddenly the broad deeply eroded valley stretches out before the observer and a surprising view is given. With the greatest regularity several terraces rise one above the other and on the Wisconsin side at the same altitude can be readily followed as a step-like descent to the bottom of the valley.

The upper terraces are washed out of the diluvial formation; the lower ones lying partly in the Lower Silurian dolomyte, partly in the Potsdam or St. Croix sandstone which was formerly distinguished by American geologists as an older member of the Lower Silurian. Along the upper St. Croix are added the great eruptions of melaphyr and melaphyr-porphyry which form the base of the Silurian system in the vicintiy of lake Superior and which I shall have opportunity during this work to revert to more in detail.

* * * * On a geological map of Wisconsin published in the year 1869 by I. A. Lapham of Milwaukee, in place of these four formations [referring to Owen's map of 1851] there is but a single formation "trap," which branches from the southwestern point of the granitic and metamorphic rocks of Wisconsin. This comprehension is the proper one, as we shall see shortly that the crystalline rocks of the St. Croix are older than the Silurian sandstone. Similar formations of that which American geologists call "traprock" are found plentifully embedded in and on the edge of the Archæan

formation in Wisconsin, particularly in conjunction with quartzytes and conglomerates of Huronian age.

Owen regarded these rocks of the St. Croix as "porphyritic trap" and compared them with the Norwegian porphyry as found on the western side of Christiana-fjord at Bogstadt.* I also regarded it originally as a porphyry or a porphyry without quartz, under which name I first introduced it in 1871. Now, however. professor Streng found not only in the matrix of this rock but also in the porphyryritically disseminated crystals, besides the plagioclase only augite and its decomposition products (chlorite, or viridite and epidote) with very little orthoclase; and for this reason this rock is decidedly more basic than porphyrite, and should be rather placed with the melaphyrs†. The character of this rock upon the whole is nearly uniform; only in places are the porphyritic and amygdaloidal structures more abundant than in others. The matrix is cryptocrystalline and of a dark-green color; under a magnifier can be distinguished dark-brown to black banded feldspars and a transparent yellowish-green mineral, which has proved to be epidote, and probably was transformed from augite. Instead of placing it with the melaphyrs one could probably refer this rock of the St. Croix valley with equal correctness to diabase since the microscopic examination has shown both the constituents of diabase and the particular alteration peculiar to it, and further, that olivine and an amorphous matrix are totally wanting. Diabases of Huronian age south of lake Superior in Wisconsin and Michigan are besides of common occurence. * * * * Besides Lingula and probably Obolus-valves I found in these Silurian strata only glabellas of trilobites the size of peas (*Conocephalus* cf. *minutus*). Of Lingula there is a form with a long pointed beak associated with much shorter and broader ones. Examples of the first attain a length of 15^{mm}. At first view one thinks he sees the well known *Lingula antiqua* and *Lingula prima* but of much larger size than those we are accustomed to meet with. The nature also of their association leads at once to the supposition that we have here the differently formed valves of but one and the same species. The large form with pointed beak Owen described as *Lingula pinnaformis*. His illustrations, however,

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*Owen's Geological Survey, page 161.

†Ueber die Krzstallinischen Gesteine von Minnesota, von A. Streng und J. H. Kloos, in *Leonhard's Jahrbuch*, 1877, pp. 49-51. [See translation of this in the Eleventh Annual Report. N. H. W.]

do not allow of its being distinguished from the *Lingula acuminata* Conrad* and in the description he does not point out the differences between it and the earlier described forms of the oldest Silurian. Later James Hall recognized the species *Lingula pinnaformis* Owen, noting, however, that the muscle impressions of all these valves, so far as he had observed, showed sufficient differences from true *Linugulae* to elevate the St. Croix form into a distinct genus and to which he gave the name *Lingulepis*†. At the same time he refers the shorter and broader form to *Lingulepis* but leaves it in doubt whether they belong to one or two species. Owen also cites from this locality *Lingula ampla* and *Orbicula prima*, both named by him, as well as *Lingula antiqua* and *prima* (?).

So far as the occurrence of all these species at St. Croix Falls is concerned it is positive that these identifications, as shown already by Hall,‡ with *Lingula ampla*, rests partly on mistaking one thing for another and erroneous identifications. Owen's figures are too poor to admit of comparisons being made with other localities, and Hall, who had a large amount of material from St. Croix Falls at his disposition, admitted that he could not make out Owen's species.

The material which is at my command is unfortunately insufficient to thoroughly work out the fauna of this oldest Silurian stratum, and I am compelled in this to wait until I shall again have the opportunity of visiting these localities. Besides *Lingulepis pinnaformis* Owen, there can probably also be identified an *Obolus* which particularly occurs in the pyritiferous marl-slate, but also in the limestone layers associated with *Lingulepis*. Externally it very much resembles the *Obolus appolinis* Eichwald, of Russia, and it is only, upon the whole, larger, attaining a length and breadth of 11 mm. The thin valves are irregularly concentrically striated and show an exfoliation of the outer layers, particularly towards the anterior edge, also a fine longitudinal lining. The greatest breadth lies somewhat below the middle, the lateral margins converge towards the beak and there form an angle of about 50°. On a single example only was it possible to uncover the muscular-impressions; they do not entirely agree with the drawings of *O. appolinis* as

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*From the Potsdam sandstone of Canada, compare Geolog. Report of Canada for 1864, p. 109.

†See Cont. to palæontology in the sixteenth Ann. Rep. of Regents of the University of New York. Appendix D. p. 129. Albany 1863. This work of the American palæontologist unfortunately came into my hands long after my visit to these localities

‡L. C., page 125.

given by Davidson, in that the adductors instead of having an oblique direction and converging downwards towards the middle, are disposed in a straight line and stand perpendicular on the axis of the shell. With the small *Obolella* species from the Cambrian strata of England, the muscular impressions have also only a distant resemblance; agreeing no better with true *Lingulas* and with the illustrations of *Lingulepis*. It would be risky to found a new species upon this single example, and I prefer not to decide the questiou as to the proper disposition of those St. Croix brachiopods not belonging to *Lingulepis pinnaformis**

THE UPPER HURONIAN SLATES OF THE ST. LOUIS RIVER.

A third river which in central Minnesota demands the closest attention of the geologist is the one already named in the introduction, viz., the St. Louis river. It also offers for a great distance the only possibility of a view of the geognostic relations, Still more than on the St. Croix and on the upper Mississippi are here all explorations made more difficult, on account of the enormous forests and the extensive swamps. One reaches the St. Louis river now more easily by the railroad between St. Paul and lake Superior which was completed in the year 1869. This railroad follows at a small distance the course of the St. Croix and rises gradually from 700 feet at St. Paul to 1170 feet above the ocean level. Here it crosses the water-shed between the tributary streams of the Mississippi and those flowing in a northerly direction into lake Superior. This point is 120 miles distant from St. Paul and 35 miles from the western arm of lake Superior.

Outside of a few cuts in the Trenton limestone in the vicinity of St. Paul, the region along the Lake Superior railroad affords no exposures of the underlying rocks until one reaches the water-shed. Extended forests composed mainly of pines, firs, etc., stretch out on both sides. The country is flat and swampy, the brooks and water courses are cut but little into the surface. In the cedar-marshes, through which the railroad has been built on the hights of the water-shed, the first rocks project.

*Although the material still in my possession is not sufficient to positively determine the proper relationship of the St. Croix river linguloid, yet the rich material at hand from other regions and in the Göttinger collection which my highly honored teacher professor Von Seebach, with the greatest willingness placed at my disposal, has assisted much to settle earlier wrongly-formed opinions, for which I should not neglect in this place to express publicly my thanks as well as for his general readiness to help and teach me.

They are steeply inclined, darkish slates whose stratified knobs are elevated but a few feet above the marsh. Where the railroad company has built a high bridge over the river in the vicinity of the new village Thompson, we there have the first opportunity to study more closely these slates. Here the water has broken through these steeply inclined slates and has formed over it a series of falls and rapids which in a few miles descend 370 feet and are known as the "rapids of the St. Louis river."

Particularly fine are the slates exposed in the railroad cuttings at the junction of the Lake Superior R. R. with the Northern Pacific. One can here follow the strike for a distance of half a mile without interruption as well as the dip of the strata which the slatiness proves with accuracy. The strike is nearly direct east and west, while the dip varies between 30° and 50° toward the south. Strata of a crystalline clay-slate alternate very regularly with a rock which on first view reminds one of many German grauwacke-slates such as one often meets with in the Kulms-grauwacke of the Upper-Hartz. This simply crypto-slaty rock I am now led, since the microscopic examination, to regard as a horn-slate.

The protrusions of the clay-slates are jagged and rough, while the intermediate layers, which in contrast with the clay-slates that have been wrought variously as roofing-slates, must be regarded as very imperfectly slaty, are smoothed off and more or less excavated in such a way that when one walks over the slate-complex perpendicular to the strike, the clay-slates form the ridges and the horn-slates the troughs. The thickness of the different strata is various; on the railroad I measured several clay-slate strata from 25 to 30 feet thick, while the intermediate beds of horn-slate are in general somewhat less in thickness. In other places however the thickness is considerably greater, and there are places where large quarries have been opened for the obtaining of roofing-slates. The transverse slatiness, which warrants this, passes through the entire clay-slate strata and shows in connection with the changeable dip of the strata a constant direction from 75° to 77° toward the south. Crevices filled with quartz, calcspar and feldspar are of common occurrence throughout the entire strata-complex.

For a long time uncertain where to place the rock here named horn-slate, I received my clue from a microscopic examination of it. A detailed description is therefore necessary. The color can be called a light green. This rock to the naked eye appears entirely compact although with many minute white and

luminous dots which under a magnifying glass prove to be very small quartz and feldspar crystals, or grains, and which are imbedded in a felsitic matrix with a splintery fracture. Under the microscope there appears an irregular aggregation of quartz-grains and feldspar-crystals, and this is traversed in all directions by a dirty-greenish granular substance through which the whole receives the appearance of an irregular mesh or network. In quantity the quartz is predominant; the feldspars are prevailingly striated.

Where the green-colored substance is massed in somewhat greater quantities between the quartz and feldspar-crystals one can plainly observe that it shows no pleochroism between crossed nicols on rotating the preparation, as it remains totally dark. Under stronger magnification it dissolves itself into greenish, pipe-like bodies, flakes, pellicles and in still smaller, short, apparently colorless microliths, which however by turning the micrometer screw also become green and are therefore sections of flakes lying in the various strata of the preparation. Where the pipe like bodies, filled with a greenish pigment, lie between neighboring quartzes and feldspars, a parallel arrangement among them can be detected, and they are placed at right angles on the edges of the crystals. They also penetrate into the quartz and feldspar and sometimes completely fill the latter while the quartz usually appears clear and does not show many cavities or dark-edged bubbles. Rarely was I able also to discern moving bubbles. Yet the quartz could be sufficiently recognized by its clearness, smooth surface and active polarization. Magnetic iron appears in small, separated accumulations which by the strongest magnification dissolves only along the edges into small grains. The similarly formed particles of a dirty-brown color originate apparently from the decomposition of the magnetite.

We therefore have here an imperfectly slaty, crypto-crystalline rock composed of quartz, plagioclase, a greenish chloritic mineral and magnetite, with a sub-crystalline clay slate regularly interstratified, which agrees in its construction and nature with the horn-slates as it was recently described by R. Credner* from the older slate-formation of Saxony and which was formerly called felsyte-slate. This rock apparently was regarded by Norwood as well as by Eames as green stone. Its regular alternation with the roofing slate in thin beds but in a very

*Compare G. R. Credner das Grünschiefer system von Hainichen im Kgr, Sachsen, in der Z. f. d. Ges. natur Wiss, 1876, B. XLVII, S. 25 ff.

thick and widely distributed slate-complex, points however decidedly against the acceptation that we have here to deal with a massive rock.

For comparison with the horn-slate I also undertook a detailed microscopic examination of the roofing-slate. The following description is based on a thin section made parallel with the cleavage-planes. Only under strong magnification does this exceedingly fine-grained slate-rock resolve itself and then into the same greenish substance which to some extent forms the cement in the horn-slate between the quartz and feldspar crystals; only that in the roofing-slate it has a far greater share in the composition; one sees, besides this, but comparatively few sections of an anomalous nature which are first brought out by polarized light.

The pale-green substance is throughout not columnar and fibrous but chloritic and decidedly scaly; one distinctly recognizes the same flakes and pellicles as in the clay-slate and can observe how the flakes partly cover and are superimposed on one another. In polarized light they show no change but remain dark in turning the thin section between crossed-nicols. Of the larger sections there are two kinds: light, slightly colored and dark. Some of the light-colored ones give distinct evidence of mica scales. They polarize very lively, have a very irregular shape and are mostly fringed, also often creased and bent over on the edges. They are, however, to be regarded as clastic particles. All these nearly or altogether colorless sections cannot, however, be referred to mica, as a part of them appear to be quartz. The dark sections are sometimes almost square, occasionally rhomb-shaped and often wholly irregular in form. Their color appears in polarized light light-yellow, yet they are generally filled with a black untransparent substance which often causes them to appear as opaque particles. In direct light they appear in the dark field as faint yellow in color; in rare instances they attain the size of 0.1mm. the majority, however, remain below 0.01mm. in the largest section. The appearance signifies that these bodies are epidote.

Besides these larger sections one discerns, however, under a magnification of 400 diameters, still more numerous smaller needle-shaped forms which under crossed-nicols appear in the dark chloritic matrix as bright, shining, short threads. In turning the section they become light and dark and also exhibit faint colors; rarely do they attain a length of 0.5mm. with great thinness; generally, however, they are not over 0.005mm. long,

and when compared to their length, somewhat broader. Magnetic-iron can be observed in somewhat large dust-like accumulations. Only with great effort, and after many failures, was it possible also to prepare a thin section transverse to the cleavage of the roofing-slates sufficiently thin and transparent to distinguish the various particles. This showed, first of all, that in contrast to the above observed mica- slates the slatiness is not dependent upon the position of the scales of a single element (in that case of the mica), but on the contrary that all particles have a stretched layering. With this there also appears a net-like stucture, in which the colorless, pellucid elements in parallel lentile-shaped aggregates are surrounded by a green chloritic substance. These now appear in transverse section between crossed nicols different from the picture presented in the longitudinal section. There is namely a polarization appreciable and at the same time a lamellar or fibrous structure in the sheets, parallel with the cleavage. These are shown plainest when the direction of the layers forms an angle of 45° with the principal sections of the nicol-prisms; when it coincides with one of the principal sections, the green scales appear totally dark. Thin splinters of the roofing-slate can with the aid of a blow-pipe be melted into a dark-green glass; the thinest splinters of the horn-slate, however, can only be rounded on the edges; after heating the pale green of the transparent edges of the splinters changes to an opaque brown-green. Muriatic acid had no effect upon the sections of the roofing-slate even after heating; powdered it was not appreciably affected by sulphuric acid.

After all this the difference between the horn-slates and the interbedded roofing-slates appears in the greater content of quartz and feldspar, while the latter contains more chloritic properties, and microlites the proper reference of which remains uncertain.

Midway between Thompson and Fond du Lac, a small village on the St. Louis river and up to which point this stream is navigable, the above slate system is uncomformably overlain by sandstone layers of the Lower Silurian. Lake Superior, as is known, forms a basin in these strata and repeats the same interrelations along the whole south shore*. Everywhere the Potsdam sandstone lies in undisturbed deposits upon the slate knolls

*Compare the above mentioned geological map of Wisconsin and H. Credner's: Vor silurische Gebilde der "Oberen Halbinsel von Michigan" in der Zeit. der deut. geol. Gessel., 1869, pages 531 and 550.

of the great clay-chlorite-talk slates and quartzytes which together form the Huronian formation. Although I found no organic remains in the sandstone strata of the St. Louis river yet they undoubtedly belong to the Potsdam sandstone as one can conclude with reasonable certainty from analogy with its widely distributed and often repeated stratigraphic relations along lake Superior, and that these roofing and horn slates must be assigned to the Huronian.

A local disturbance of the inter-relations of the strata does not exist on the St. Louis river. The position of the slates of the older strata is similar, so far as opportunity to observe them has been afforded, everywhere in the regions of the Archæan slates. I also did not find in the vicinity any crystalline rocks to whose influence Norwood had earlier ascribed the position of the bedding, even though it may have been possible for him to give the direct proof of it. I do not doubt but that further examination of this portion of Minnesota will show a similar development of the Huronian system as that already described in detail for northern Michigan. * * *

The Silurian Melaphyr and Gabbro of Lake Superior.

The great clay masses already alluded to in the description of the diluvium which on lake Superior is distinguished by its prevailing red color, along the lower course of the St. Louis river conceal the older formations from the view of the observer. This certainly very young formation, which has never furnished organic remains, rises above the water level from 600 to 700 feet. It is on account of these deposits, that the relations between the Lower Silurian and the crystalline rocks cannot be determined and which on the western arm of lake Superior forms the shore.

At the terminus of the Lake Superior railroad near the steep cliffs where a few years ago the new city of Duluth originated, at several places these rocks are well exposed. They form almost the entire left shore of St. Louis bay and the bay of Superior. The former is a widening of the mouth of the river; the latter is formed by a narrow extension of the land separating a portion of the lake, and because of its protected position it forms a harbor much sought after.

The configuration of the western end of lake Superior is a most remarkable one. Narrow points branch off from the shore

parallel with one another, and meet similar extensions from the opposite shore of Wisconsin. They still have between their extremities narrow openings affording entrance to the inner waters. The outer of these land extensions "Minnesota point" is six miles long and has a general width of only 600 feet. It consists of coarse pebbles (*shingle*) and is elevated but few feet above the water-level. The pebbles have a longish, flattened shape and consist mainly of melaphyrs and amygdaloids with larger and smaller calcspar amygdules, which one finds contiguous in the immediate vicinity.

Connor's point in Wisconsin and Rice's point in Minnesota divide St. Louis bay from the bay of Superior. Between them there is a 50 feet deep channel through which the waters of the St. Louis river flow into the lake. Superior bay has its greatest depth along the Minnesota shore. In Wisconsin the inhabitants had to build out into the bay several hundred feet to procure a depth of nine feet, while on the Minnesota side the water has a depth of 15 to 18 feet. A street of Duluth now follows along Minnesota point; the railroad company has cut the same near its junction with the land and has made an artificial water-way protected by a strong breakwater. The natural entrance six miles farther south is variously exposed to filling up with sand; this entrance is being continually improved by the inhabitants of Wisconsin and more particularly by the city of Superior, a competitor with the new town Duluth.

In the cliffs near the city of Duluth at the time of my visit, the soil and red clay had been removed in places by the building of streets. There appear essentially two totally unlike crystalline rocks. One of these, which was particularly well exposed at the railroad depot, I have already given in my first notice of Minnesota as a gabbroid or hypersthene rock. Since the examination by Prof. Streng it has actually proven to be gabbro; the preponderance of labrador-plagioclase with equal quantities of hornblende and diallage led him to regard it as hornblende-gabbro. Noticeable in this rock is the enormous wealth of feldspar and the great paucity of other elements, which are, except the titanic magnetic iron, difficult to detect between the feldspar-crystals and can only be distinguished with sufficient clearness in thin sections. The distinct twinning-striation, the plainly marked cleavage planes, the lustre and beautiful changeable colors, and the results obtained in the analysis of this rock all point to the labrador nature of the feldspar.

The pecular formation of this rock lends probability to the surmise that it is stratified—opposed to which, however, is the general distribution which it occupies on the cliffs along the St. Louis river. Unfortunately it was not possible to observe the contact relation with the other rock series. Its last appearance is several miles away from the Lower Silurian strata, and towards lake Superior the dense primeval forests conceal it from observation.

This rock, erroneously named Duluth granite, has recently found a common use in monumental work as it receives a very high polish.

A short distance beyond the gabbro (i. e. toward the east) the beautiful porphyry-like melaphyr forms the first rocky masses on the shore of lake Superior. In contrast with the gabbro above described is a green rock of similar composition, which forms on the St. Croix river the support of the Potsdam sandstone, and has here a prevailingly brown color and greater tendency to embrace amygdaloids. The latter are therefore on the western shore of the lake widely distributed and pass gradually into the compact rock. Under a magnifier one soon recognizes that the prevailingly brown muddy coloring is due to a profound separation of the individual elements, and the examination of a thin section shows particularly the feldspar to be impregnated with a granular substance which in the greatest magnification is no more definable. The presence of epidote, which mineral is secreted in various forms on the hills, and appears in conjunction with calcspar, laumontite, and a dusty iron-and-a-manganese-rich substance, as if impregnating the matrix of the melaphyr, points likewise to the change which the original elements have suffered.

At one place only was there a slight break in this rock, and there it seemed to appear fresher, having a dark green-to-black color. Here it appeared in connection with fine non-porphyritic melaphyr; whereas the immediate passage into the brown, epidotic, melaphyr-porphyry, which has a much larger distribution, was not discernible.

In the amygdaloids, into which the brown melaphyr passes insensibly in several places, the decomposition of the matrix has gone on considerably further. The longish cavities are filled with quartz, calcspar, a chlorite-like mineral and the above mentioned dark, dusty substauce. There are also long crevices attaining several inches in size which are filled with large calcspar leaves, laumontite and epidote. Of a filling of the amyg-

daloids and crevices with copper or salt of copper, as it occurs on the north and south shores of lake Superior in the trap-like rocks of the Huronián and the Lower Silurian. not a trace was discovered at Duluth.

Although it cannot with certainty be stated what relation the melaphyr and gabbro of Duluth have with the sedimentary rocks, yet where the above described formation appears on the St. Louis river, the succession appears to me to allow the conclusion that the shores of the western arm of lake Superior are made up of beds in the Potsdam sandstone. and that they probably consist of dike-like intrusions. From the descriptions of Owen, Whittlesey, and others, we know that trap-like rocks, *i. e.* melaphyrs, play a great part on the north shore of lake Superior, and that they appear partly in a conformable position with the strata of the Potsdam sandstone and partly as dykes.

A ridge continues along the northern shore, and is composed of crystalline slates and other Archæan rocks. It extends from four to six miles into the land, with its greatest elevation from 600 to 1,000 feet above the water level. From the crest of this ridge the rocks descend gradually towards lake Superior, and here lie against the Silurian strata with a southerly dip. A number of winding streams have their origin on this ridge, rapidly descending through the various massive and stratified rocks, affording numerous exposures of the relations of the often very complicated strata. Some of these by their indications of copper have obtained a certain notoriety, and are still regarded as rich in copper by many people; this is particularly so in the French and Knife River districts, which are also within the limits of Minnesota.

To similar intrusions the above mentioned land-projections, which extend in front of the St. Louis river in a manner similar to the low ground in front of the river-mouths of northern Germany. point; but here they have a totally different origin.

Whittlesey has set up the proposition that the trap-like rocks, which contain metallic copper, are of the age of the Potsdam sandstone, while those containing sulphides belong to the Huronian.* And also that the copper bearing dykes become barren as they pass from the "trap" into the sandstone. The first portion of this proposition if proven would be of great importance to Lake Superior copper mining, still I believe I am forced to doubt its general accuracy. The dia-

*Whittlesey's Report of 1866, page 5.

base-like melaphyr of the St. Croix river, which is older than the Potsdam sandstone, is numerously traversed by dikes, in which of course now and then occur sulphides. Constantly, however, I found with it also pure copper in soft leaves and segregations or in threads, thin sheets, even in wire and button-shaped masses.*

On the other hand, a dike-rock from the horizon of the Potsdam sandstone of the Knife River district, about 30 miles east of Duluth, had, besides pyrite, only sulphuret of copper in slight segregations, without a trace of pure copper.

At most localities where Huronian or Silurian melaphyrs appear, traces of copper have been found in the crevice-fillings. On the surface of the melaphyr of the St. Croix river one often sees feldspar veins of but few inches thickness which become wider at greater depths. One of these veins which could be traced on the surface for several hundred feet had at a depth of twenty feet a thickness of nearly 2½ feet. The samples from this depth consisted of a much decomposed rock rich in feldspar and lime, traversed with pure copper and sulphurets, however, only in small segregations and not in sufficient quantities to undertake large trial workings.

The larger masses of pure copper which up to this time have occasionally been found in Minnesota, come from the boulder-strewn hills of the diluvium. I also met with them along the river beds of the St. Croix and the Kettle rivers, and also from the eastern portion of the city of St. Paul. As similar copper drift has been found much farther south, even in the state of Ohio, in the "drift formation" one is justified in looking for their origin in the vicinity of lake Superior, and it is certainly to be deplored, as still often happens, that such foundlings awaken an expectation of finding a great richness of copper in the vicinity.

A short resumé of the results obtained and a condensed view of our present knowledge of the geognostic relations of Minnesota may conclude these observations.

Within the limits of this state there have been determined with accuracy: the Archæan series; the strata of the Lower Silurian and Middle Cretaceous ages. In the southern part of the state there can probably also be added the Upper Si-

*Compare J. Kloos Geol. Notizen aus Minnesota, in der Z. d. deutschen geolg Gessel. 1871, page 445.

lurian strata, which, however, soon thin out and have as yet furnished no characteristic fossils.

The Archæan group in the middle portion of the state is particularly represented by massive crystalline rocks, chiefly composed of non hornblendic and hornblendic granites (syenite granites), diorites (augite diorytes) as well as melaphyr-like rocks. Upon these succeed the crystalline slates, namely mica-slates, horn-slates and chloritic slates, which are usually formed as roofing slates and in which gneiss is observably wanting or at least very inconspicuous. In the north the crystalline, massive and slaty rocks have a very large distribution, and there it can be shown that the sequence of the Laurentian and Huronian systems is analogous to that of Canada, Michigan and Wisconsin. The Archæan slates through lateral pressure are similarly elevated over great areas, as can be observed everywhere along the edges of the massive Laurentian. On the knolls of the younger Huronian, preponderateingly chloritic-slates, or on the diabase-like melaphyrs, which belong to the same age, lie in a horizontal position the Lower Silurian sandstone strata. The latter have a great distribution and join directly the strata of the same age in Wisconsin. They are similarly traversed there as in western Canada by melaphyrs; melaphyr out-pourings have also spread over them and now alternate with them while they are again traversed by copper-bearing dikes. As probable inclusions in the Potsdam sandstone can also be added the hornblende-gabbro of Duluth.

A rock with hardly less areal distribution than the Potsdam sandstone is the following member of the Silurian—the lower dolomyte of the Mississippi; it is a constant associate with the sandstone. Of far less importance, however, are the younger strata; as the disintegrating nature of the St. Peter sandstone has caused the disappearance of this as well as the super-imposed destructible strata of the Trenton limestone over great areas in the central portion of the state, and it now appears in several separated regions. The Silurian strata apparently lie everywhere horizontal but have a slight dip which in the southern part of the state is southerly while beyond Mountain lake it is toward the north.

Above the Silurian the various formations are wanting up to the Cretaceous period, at least none have been seen up to this time. It appears, therefore, that this middle portion of the North American continent during this enormous time was elevated above the ocean surface. In the wide valleys of the

Mississippi and St. Peter rivers there can also be seen evidences of great erosion, and at St. Paul on both sides of the stream it is apparent in the vast accumulation of boulders composed almost entirely of Silurian limestone, how powerfully these strata have been affected.

First during Cretaceous times was the western portion of the state again covered by the sea, and it formed a portion of the great Cretaceous ocean whose deposits can be studied along the Missouri in the most complete manner. The eastern shore of this great salt-water basin lay within the present region of the Mississippi. Whether Tertiary deposits were present, and later have disappeared through erosion to a few outliers, is uncertain. The predominating clayey and sandy Cretaceous formations have at least again suffered great erosion.

Diluvial formations are represented in great thickness and cover the southern and middle portions of the state, making it very difficult to investigate the lower formations. These youngest deposits can be separated into two natural groups,—the clayey-marls and the sandy gravel diluvium; and, further, the latter covers the unstratified clay and marl beds where the two come together.

The diluvium determines the configuration of the ground and forms adjoining step-like successions of table lands. The largest and deepest river valleys penetrate the diluvium to the Silurian and Huronian strata; the majority of the water-courses, however, have cut down only to the clayey diluvial deposits. The massive rocks of the Archæan group in the vicinity of the Mississippi and in the valleys of the Sauk and St. Peter rivers project above the diluvial formation. These are also for the greater part removed from observation by the plateau like diluvial deposits and only in the presence of a higher plateau, which on the St. Peter and Mississippi rivers joins with that of the northern part of the state, give evidence of the existence of a tongue of Laurentian rock transversely traversing the state. The restricted hill ranges towering above the table-land consist mainly of accumulations of boulders and presumably had their origin in currents or by the action of later erosion. Of high interest are the hydrographic relations of the low watersheds separating the great river systems. The waters now flow from a central high plateau in three directions; it is, however, probable that the northerly direction of the western stream, the Red river of the North,

was first given to it in recent times, and that at an earlier date all waters found an exit either towards the south through the Mississippi valley or easterly through the great lakes.

III. CHEMISTRY.

REPORT OF PROFESSOR JAMES A. DODGE.

UNIVERSITY OF MINNESOTA,
Minneapolis, Nov. 30, 1891.

Professor N. H. Winchell.

DEAR SIR: I hereby submit to you, for publication in the report of the State Geological Survey, a copy of the results of the chemical analyses of minerals, etc., made for the survey by the Chemical Department of the University since the last report.

CHEMICAL SERIES NO. 194.

A sample of black sand. Analysis by J. A. Dodge.

Silica	SiO_2	5.19 per cent.
Alumina	Al_2O_3	2.95 " "
Lime	CaO	traces
Magnesia	MgO	.35 " "
Oxide of titanium	$Ti'O_2$	36.77 " "
Protoxide of iron	FeO	32.29 " "
Magnetic oxide of iron	Fe_3O_4	22.10 " "
Phosphorus		none.
Sulphur		none.
Chromium		none.
Total		99.65

This sand was but little attracted by the magnet.

CHEMICAL SERIES NO. 195.

A sample of iron ore. Analysis by J. A. Dodge.

Metallic iron		47.07 per cent.
Phosphorus		.09 " "
Oxide of titanium	TiO_2	traces.

CHEMICAL SERIES NO. 196.

A dark gray crystalline rock. Analysis by J. A Dodge.

Oxide of titanium.................. TiO_2 none.

CHEMICAL SERIES NO. 196'.

Supposed gold ore. Assayed by C. F. Sidener.

Gold, none. Silver, none.

CHEMICAL SERIES NO. 197.

A hematite ore. Analysis by C. F. Sidener.

Silica	SiO_2	8.25	per cent.
Alumina	Al_2O_3	traces.	
Lime and magnesia		traces.	
Ferric oxide	Fe_2O_3	92.08	" "
Manganese		none.	
Titanium		none.	
Sulphur		none.	
Phosphorus		.09	" "
Total		100.42	

CHEMICAL SERIES, NO. 198.

A sample of ore. Analysis by C. F. Sidener.

Silica,	SiO_2	39.70	per cent.
Arsenical pyrites		60.30	

CHEMICAL SERIES NO. 199.

A sample of kaolin. Analysis by C. F. Sidener.

Silica	SiO_2	63.64	per cent.
Alumina	Al_2O_3	24.95	" "
Ferric oxide	Fe_2O_3	4.90	" "
Lime	CaO	1.02	" "
Magnesia	MgO	.20	" "
Soda	Na_2O	.66	" "
Potassa	K_2O	.31	" "
Water and organic matter		4.32	" "
Total		100.00	

CHEMICAL SERIES NO. 200.

A reputed ore of silver, from the "Silver Star Lode," near Cable, Wis., sent by Mr. F. L. McKusick, of Stillwater, Minn. Assay by J. A. Dodge.

Gold	very slight traces.
Silver	none.

CHEMICAL SERIES NO. 201.

A sample of water from a deep well at Stillwater, Minnesota. Analysis by C. F. Sidener.

Chlorine	30420 parts per million.
Bromine	240 " " "

Reduced to grains per gallon U. S.

Chlorine	1,774.4 grains.
Bromine	14.0 "

CHEMICAL SERIES NO. 202.

An olivinitic magnetite. Analysis by C. F. Sidener.

Silica	SiO_2	11.39	per cent.
Alumina	Al_2O_3	traces.	
Magnetic oxide of iron	Fe_3O_4	85.55	" "
Lime	CaO	.22	" "
Magnesia	MgO	3.44	" "
Oxide of titanium	TiO_2	none.	
Sulphur		traces.	
Phosphorus		.02	" "
Total		100.62	

CHEMICAL SERIES NO. 203.

A titaniferous magnetite. Analysis by C. F. Sidener.

Silica	SiO_2	11.37	per cent.
Alumina	Al_2O_3	1.32	" "
Magnetic oxide of iron	Fe_3O_4	53.33	" "
Protoxide of iron	FeO	14.42	" "
Oxide of titanium	TiO_2	16.03	" "
Lime	CaO	.10	" "
Magnesia	MgO	2.73	" "
Sulphur		traces.	
Phosphorus		.01	" "
Total		99.31	

CHEMICAL SERIES NO. 204.

A green siliceous rock. Analysis by C. F. Sidener.

Silica	SiO_2	50.47	per cent.
Alumina	Al_2O_3	18.48	" "
Ferric oxide	Fe_2O_3	2.13	" "
Ferrous oxide	FeO	7.74	" "
Lime	CaO	6.61	" "
Magnesia	MgO	6.90	" "
Soda	Na_2O	2.58	" "
Potassa	K_2O	.30	" "
Water	H_2O	2.34	" "
Phosphorus		traces.	
Total		97.52	

CHEMICAL SERIES NO. 205.

A magnetic iron ore. Analysis by C. F. Sidener.

Silica	SiO_2	11.85	per	cent.
Alumina	Al_2O_3	.34	"	"
Magnetic oxide of iron	Fe_3O_4	87.00	"	"
Lime	CaO	.20	"	"
Magnesia	MgO	.80	"	"
Oxide of titanium	TiO_2	none.	"	"
Sulphur		traces.	"	"
Phosphorus		.056	"	"
			"	"
Total		100.246	"	"

CHEMICAL SERIES NO. 206.

A limonite ore. Analysis by C. F. Sidener.

Silica	SiO_2	3.52	per	cent.
Ferric oxide	Fe_2O_3	87.10	"	"
Lime	CaO	traces.	"	"
Magnesia	MgO	traces.	"	"
Sulphur		traces.	"	"
Phosphorus		.023	"	"
Water	H_2O	9.70	"	"
Total		100.343	"	"

CHEMICAL SERIES NO. 207.

A sample of borings from a well at Mankato, Minn., consisting mainly of magnetic oxide of iron. Analysis by C. F. Sidener.

Oxide of titanium.................. none.

CHEMICAL SERIES NO. 208.

A sample of rock, showing black mica, feldspar and quartz, reputed to contain silver. Assay by J. A. Dodge.

Silver............................ none.

CHEMICAL SERIES NO. 209.

An iron ore. Analysis by C. F. Sidener.

Silica	SiO_2	10.90	per	cent.
Alumina	Al_2O_3	5.83	"	"
Ferric oxide	Fe_2O_3	70,39	"	"
Ferrous oxide	FeO	8.75	"	"
Lime	CaO	1.20	"	"
Magnesia	MgO	1.50	"	"
Sulphur		.47	"	"
Phosphorus		.022	"	"
Oxide of titanium	TiO_2	none.		
Total		99.062	"	"

CHEMICAL SERIES NO. 210.

An iron ore. Analysis by C. F. Sidener.

Silica	SiO_2	3.62 per cent.
Alumina	Al_2O_3	traces.
Ferric oxide	Fe_2O_3	95.76 " "
Lime	CaO	traces.
Magnesia	MgO	traces.
Sulphur		none.
Phosphorus		.093 " "
Total		99.473

CHEMICAL SERIES NO. 211.

A siliceous material with a somewhat foliated appearance Analysis by J. A. Dodge.

Silica	SiO_2	60.05 per cent.
Alumina	Al_2O_3	27.55 " "
Ferric oxide	Fe_2O_3	1.30 " "
Lime	CaO	.38 " "
Magnesia	MgO	.77 " "
Soda	Na_2O	.31 " "
Potassa	K_2O	4.26 " "
Phosphoric oxide	P_2O_5	.11 " "
Water	H_2O	5.30 " "
Total		100.03

The material is to be regarded as a kaolin mixed with some undecomposed feldspar.

CHEMICAL SERIES NO. 212.

A sample of quartz and pyrite. Assay by J. A. Dodge.

Gold	traces.
Silver	none.

CHEMICAL SERIES NO. 213.

A sample of quartz and pyrite. Assay by C. F. Sidener

Gold	none.
Silver	none.

CHEMICAL SERIES NO. 214.

A green mineral. Analysis by C. F. Sidener.

Silica	SiO_2	43.96	per	cent.
Alumina	Al_2O_3	16.03	"	"
Ferric oxide	Fe_2O_3	10.50	"	"
Ferrous oxide	FeO	8.74	"	"
Lime	CaO	9.54	"	"
Magnesia	MgO	6.56	"	"
Soda	Na_2O	1.62	"	"
Potassa	K_2O	.27	"	"
Water	H_2O	1.84	"	"
Total		99.06	"	"

CHEMICAL SERIES NO. 215.

A dolomitic rock. Analysis by C. F. Sidener.

Silica	SiO_2	2.70	per	cent.
Alumina	Al_2O_3	.35	"	"
Ferric oxide	Fe_2O_3	17.23	"	"
Ferrous oxide	FeO	8.35	"	"
Carbonate of lime	$CaCO_3$	49.80	"	"
Carbonate of magnesia	$MgCO_3$	19.65	"	"
Soda	Na_2O	.20	"	"
Potassa	K_2O	.04	"	"
Water	H_2O	.47	"	"
Total		98.79	"	"

CHEMICAL SERIES NO. 216.

A sample of crystalline rock. Analysis by J. A. Dodge.

Silica	Si_2O	67.42	per	cent.
Alumina	Al_2O_3	15.88	"	"
Ferric oxide	Fe_2O_3	1.37	"	"
Ferrous oxide	FeO	1.14	"	"
Manganese		traces.		
Lime	CaO	3.49	"	"
Magnesia	MgO	1.43	"	"
Soda	Na_2O	6.42	"	"
Potassa	K_2O	2.65	"	"
Phosphoric oxide	P_2O_5	.07	"	"
Oxide of titanium	TiO_2	none.		
Water	H_2O	.05	"	"
Total		99.92		

Very respectfully yours,
JAMES A. DODGE, Prof. Chemistry.

NOTE.—The foregoing substances were derived as follows:

Chem. Series 194.—Iron sand, fine, a few of the grains being magnetic. Birch lake beach, one mile west of the mouth of Dunka river.

Chem. Series 195.—Iron ore, Geol. Survey No. 1024, from J. Bausman's. Schistose ore, east of Garden lake.

Chem. Series 196.—Olivinitic ore, Geol. Sur. No. 976. From SW. ¼ Sec. 10, 62-12.

Chem. Series 196'.—Supposed gold ore 258 (H) submitted by H.V.W., Aug. 22, '87.

Chem. Series 197.—Iron ore, Prairie River Falls, Geol. Sur. No. 260 A. (H). Foot of the lower falls.

Chem. Series 198.—A heavy, white, metallic ore, said to have been found on White Iron lake. (Dovonan).

Chem. Series 199.—Kaolin, from near Brownsdale, Minn. From Mr. W. M. Jones, of C., St. P. & K. C. Ry.

Chem. Series 200.—Ore from Silver Star Lode, Cable, Wis. For F. L. McKusick, to compare with report of "Lehnen" in St. Paul.

Chem. Series 201.—Brine from the Stillwater deep weell.

Chem. Series 202.—Olivinitic magnetic, Geol. Sur. No. 408 (H). SE. ¼ Sec. 30, 62-10.

Chem. Series 203.—Titaniferous magnetic, Geol. Sur. No. 414 (H). SE. ¼, NE. ¼ Sec. 36, 63-10.

Chem. Series 204.—Green rock, Geol. Sur. No. 538 B. (H). Diabasic rock, ten feet from contact with jaspityte, SW. ¼, NW. ¼ Sec. 4, 63-9.

Chem. Series 205.—Magnetic iron ore, Geol. Sur. No. 369 A. (H). SW. side of Iron lake, NE. ¼ Sec. 23, 60-13.

Chem. Series 206.—Limonite, Geol. Sur. No. 354 (H). Mallmann's working, Sec. 29, 59-14.

Chem. Series 207.—Magnetic particles from the Mankato well, (at Minneopa). First rock below the red quartzite, (No. 10 of the section).

Chem. Series 208.—Sample of gneiss, from Auditor Braden. Said to have silver—so reported by "Lehnen," from his explorers on state lands in the northern part of the state.

Chem Series 209.—Magnetic iron ore, from the north side of Long lake, from the Vermilion series of rocks, Geol. Sur. No. 543 (H).

Chem. Series 210.—An amorphous hematite, from the Mesabi (Animikie) east of Grand Rrpids; the Warner-Griffin location.

Chem. Series 211.—White kaolinic "soapstone" Geol. Sur. No. 1449, stone mine.

Chem. Series 212.—Pyritifereous quartz, Eagle lake. Geol. Sur. No. 1501. Supposed to contain gold.

Chem. Series 213.—Pyritiferous quartz, and slate, supposed to represent the "gold ores" of Vermilion gold extitement in 1870. Geol. Sur. Nos. 395, 396, 397, 398, 400, 423, 428. All used as one sample.

Chem. Series 214.—Kawasachoug rock, Geol. Sur. No. 356.

Chem. Series 215.—Dolomitic or sodoric rock, from the Animikie, on Gunflint lake, Geol. Sur. No. 312.

Chem. Series 216.—Porphyritic conglomeritic rock, from Kekekebic lake, Geol Sur. No. ——? N. H. W.

IV.—THE WOODS OF MINNESOTA.

By H. B. Ayres,

Agent of the Forestry Division, Department of Agriculture, Washington, D. C.

Among the natural stores so placed as to encourage the pioneer and develope the manly hardihood characteristic of the woodsman, the explorers of Minnesota found one of the grandest forests in one of the most accessible locations.

The conception first formed of the condition of the existing woodlands, is that all possible conditions are formed, and that they cannot be classified. Yet after the ceaseless variations have passed before the mind general classifications group themselves, and several portions of the wooded area stand out as having characteristics that distinguish them and separate the whole into groups. These groups are:

(1) The brush prairie bordering the first elevation above the plains on the south and west. The growth here is rose, hazel, thorn, plum, choke cherry, scrub oak, poplar, etc., with a stunted growth of the hardwood timber trees.

(2) The hardwood belt of oak, maple, basswood, elm, birch, poplar and ironwood on fertile undulating land dotted with lakes and broken by prairie openings. This land is now mostly in the hands of private owners, farmers, who are as a rule doing well.

(3) The jack pine and norway belt marking in general the border of a second elevation, a beach formation of sand and gravel, mostly non-agricultural, except in Hubbard Co., almost annually burned over, sparsely timbered, yet saved from denudation by the wonderful reproductive power of the scrub pine (P. banksiana), under shelter of which the norway pine (P. resinosa), develops rapidly into a valuable timber, and by the poplar under which the white pine is apt to start. This belt is well developed north west of Brainerd and no the east grades into the pine barrens of Wisconsin. It is frequently broken by areas of poplar and white birch, while much white pine exists here and there on the heavier soils.

(4) The white pine region, infinitely varied with hardwoods, norway and jack pine, cedar and tamarac swamps, and open or spruce bogs bordering the numerous lakes or occupying their old beds. In general, this region is brushy where not heavily

timbered, and so well watered with so little fall that but little white pine is more than five miles from drivable streams.

Nearly all of the streams of this region head in the open bogs, which, where partly shaded by spruce, make enormous growth of sponge-like spagnum moss holding the ice of winter until June and July and preserving a supply of water that the explorer may find under some upturned root, well into if not throughout the drought of August and September.

The soil here is usually loam or clay and supports a considerable growth of hardwood, among which the white pine reaches its most perfect development.

Much of this whole area has been stripped by fire even before the loggers increased the liability to fire by the tops they leave in the woods; and by the greater drying of the forest floor by exposure to sun and wind, in the openings they have made.

It has been estimated that thirty years ago over 40,000,000,000 feet of pine were standing on the 25,000,000 acres of forest in the state. Since that time busy milling towns have started up here and there as if by magic and loggers and choppers have swarmed into the forest until the average number of men now employed in preparing forest products for market reaches about 17,000, and the value of the product as placed upon the market amounts to about $31,635,000.

Must the industry soon decline?

The answer is a prompt and positive—No.

If timber were a deposit, like beds of iron ore, with no power to reproduce itself, we could readily estimate the time of the end.

In such a case we could see that with the present supply of standing timber—say 20,000,000,000 feet, 17 years more would leave the state stripped.

But where fire is kept out forests reproduce themselves, and the accretion by growth, while small and of comparatively little value in woods cut without any view to reproduction, in woods cut at such a time and in such a manner as to give the seedlings and sprouts the best chance to make a rapid "second growth" the annual increment under the best forest management in Europe has averaged about 55 cubic feet per acre; one-third of which should be estimated as log timber.

To produce an annual growth of 1,200,000,000 feet B. M.—(the latest annual cut)—would at this rate require 5,500,000 acres.

In mournful contrast with these results obtained in Prussia, stands the estimate, though roughly made and presented with some hesitancy, yet approximating the fact, that the 24,960,000 acres of wooded area in the state did not, last year, grow more than 200,000,000 feet B. M. of log timber. In other words 50,000,000 acres of such forest as ours in its present condition would be required to grow the amount grown on 5,500,000 acres of well managed forest. and our forests are thus only producing less than one ninth of what they might.

We must not, however, forget that of the 24,960,000 acres now wooded, probably one-half will eventually prove more valuable as agricultural than as forest land, and suould be partly cleared. This would leave the area that should always be kept in forest, i. e. the lands unprofitable for agriculture as compared with forestry, about 12,500,000 acres, which, as above, should, under management, produce twice our present annual cut of log timber, and 400,000,000 cubic feet of other material for woodworking, fuel, etc.

Every considerable tract of forest in the state is more or less depleted by fire and can only be brought into full production after many years of renovation; but should any reader be tempted to cast these estimates aside as overdrawn, I must ask him to not do so without a careful study of the subject, such as I have given it during four years of exploring that have taken me all through the wooded region and formed in me a deep conviction that, while these estimates are necessarily rough, they are based on sound principles and at least point toward and approximate the truth.

Theoretically, therefore, it seems possible that the present yield of log timber alone may be doubled permanently and that a vast increase of manufacturing industries would follow the assurance of a constant supply, and, locating themselves throughout the woods, would in every way tend toward the greatest development of the state.

Practically, however, the difficulties in the way of attaining this ideal state of affairs are so great as to try the determination and skill of our best citizens.

The difficulties attending the question of ownership before operations of any kind can be commenced are the greatest that are to be met in the whole subject. In Europe, however. where claims of private owners were everywhere to be ajusted before anything could be done, this great barrier has been overcome satisfactorily to all.

In this country, where so much of the lower grade of agricultural land is owned by the government, there should be great hesitancy in making a beginning, beyond the caution necessary to make sure that the course be the right one.

In Europe the great difficulty has been just as here, the prejudice against anything but the free use of public property and against interference of the government in the business of individuals.

But they have, first in the moumtains where the general welfare most plainly demanded it, by condemnatory proceed ings, and later, on the poorest lowlands, where the direct profits of forestry are greater than those of agriculture, by bounties to the owners of the land, made such progress during the past century that the wisdom of the movement is plainly shown, and all men who have the chance to know, combined with a desire for the public good, write in sustaining the governmental policy of securing the perpetual cultivation of forests on all the poorest lands.

OUR LAND OFFICE SYSTEM.

While the giving of from 300,000 to 4,000.000 feet of standing pine to a poor pioneer seems a paternal act on the part of the government, the actual result is putting nearly all the value of the timber into the pocket of the lumberman, to whose plant the tract may be tributary.

The settler, even when honest, can, as a rule, afford to live on a pine claim merely long enough to comply with the homestead or pre-emption law, and when he sells his pine, often gives title to the land also, when it starts upon the routine by which it is, eventually, advertised for taxes, non-productive, idle, worthless.

If we continue, as we have done, the 17,000 men now employed in reaping the great natural harvest will soon leave the country, as they have left the older lumber states; for the lumberman, under the present system of disposing of public lands, cannot think of waiting for a second growth while he can acquire new forests of standing pine at a nominal figure. His only sensible course, as far as his own interests are concerned, is to strip off the timber and abandon the land.

The time to decide upon the use to which timbered lands should be put is, undoubtedly, before they pass into the hands of individuals. They should be examined and the question decided whether they should be thrown open for settlement as

farm lands, or whether it would be best for the general welfare to have them kept in timber.

There are still in the state some 6,000,000 acres of more or less wooded land belonging to the federal government. To one looking the situation fairly in the face, would it not seem best to have all this area withheld from settlement until the soil be examined, and its adaptability determined?

The direct profits that may be expected from forestry, are not large after the virgin timber has been cut. In Europe, seldom over 5 per cent. is realized, and the American lumberman cannot be expected to act contrary to his notable common sense and shrewdness and stay and do a business that brings in 5 per cent., while he may by entering a new field, under the present land office system, get from 10 to 200 per cent. Only in exceptional cases, most favorable to growth and convenience to market, is forestry profitable to the individual. To a corporation of wood-workers the profits may be greater, but it is only the state or the general government that will be able to reap all those other benefits, such as permanency of industries, support of greatest population, etc., which, added to the direct profits possible to the individual, would bring the sum of gains well within the percentage of fair business profits.

Forest lands should therefore, as a rule, be managed by the state or by the federal government.

In Minnesota, the federal lands now vacant, and more or less wooded, amount to some..................		6,000,000 acres.
The state lands......................	600,000	
The university lands................	470,000	
The school lands....	231,000	
		1,301,000
Total public forest lands..................		7,301,000 acres.

The question as to what would be the best management of these lands has been studied and studied faithfully by many, if not by all the men upon whom their care devolved, and no doubt they have found the difficulties that they, single-handed, were unable to overcome. It is necessary that all the people be so well informed that they may, at least, be able to appreciate the efforts their chosen representatives in the local, state or federal government may make in their behalf; and while it is the plain duty of these representatives to study all the questions bearing upon the welfare of their constituent regions,

these questions are so numerous that they cannot be expected to master them all, unless those who have made special study, aid them by digests of their work.

FORESTRY IN PRUSSIA.

While some of the forestry that is practiced in Europe is for protection purposes on steep mountain slopes, where erosive torrents, destructive floods, landslides, falling rocks and avalanches make the work imperative, most of the forests there are managed for the revenues there are in them.

Some quotations from an article by Mr. Gillford Pinchot, before the American Economic Association, referring to forestry in Prussia, may be of interest here.

"All forest management may be said to rest on two closely related facts which are so self-evident that they might almost be called axioms of forestry, but which, like other axioms, lead to conclusions of far-reaching application. These are, first, that trees require many years to reach merchantable size; and, secondly, that a forest crop cannot be taken every year from the same land. From the last statement it follows that a definite, far-seeing plan is necessary for the rational management of any forest, from the first; that forest property is safest under the supervision of some imperishable guardian, or, in other words, of the State." * * * * * *

"Holding it as a duty to preserve the wood lands for the present share which they take in the economy of the nation, the State has recognized as well the obligation to hand down its forest wealth unimpaired to future generations. It has recognized and respected equally the place which the forest holds in relation to agriculture and in the economy of nature and hence feels itself doubly bound to protect its woodlands. In a word, it has been seen that in its direct and indirect influence the forest plays a most important part in the story of human progress, and that the advance of civilization only serves to make it more indispensable."

It has, therefore, steadily refused to deliver its forests to more or less speedy destruction by allowing them to pass into the hands of shorter lived and less provident owners

Even in the times of the greatest financial difficulty, when Prussia was overrun and nearly annihilated by the French, the idea of selling the State forests was never seriously entertained.

But the government of Prussia has not stopped here. Protection standing alone is irrational and incomplete. The cases where a forest reaches it highest usefulness by simply existing are rare. The immense capital which the State wood lands represent is not permitted to lie idle, and the forest, as a timber producer, has taken its place among the permanent features of the land. The government has done the only wise thing by managing its own forests through its own forest officers.

"Donner, now Overland first-meister, in a work which carries all the weight of an official document, says:

'The fundamental rules for the management of State forests are these: First, to keep rigidly within the bounds of conservative treatment; and secondly, to attain, consistently with such treatment, the greatest output of most useful products in the shortest time.' * * * * * * *

"The State believes itself bound, in the administration of its forests, to keep in view the common good of the people, and that as well with respect to the lasting satisfaction of the demand for timber and other forest produce, as to the numerous other purposes which the forest serves. It holds fast the duty to treat the government wood lands as a trust held for the nation as a whole, to the end that it may enjoy for the present the highest satisfaction of its needs for forest produce and the protection which the forest gives, and for all future time, at least an equal share of equal blessings." * * *

"The forest is a trust handed down from former times, whose value lies not only in its immediate production of wood, but also essentially in the benefit to agriculture of its immediate influence on climate, weather protections in various ways, the conservation of the soil, etc. The forest has significance not only for the present nor for its owner alone; it has significance as well for the future and for the whole of the people."

"With respect to the second class of forest property, that belonging to towns, villages and other public bodies, it is again impossible to speak for the whole of Germany except upon the broadest lines. The State everywhere exercises oversight and a degree of control over the management of these forests, but the sphere of its action varies within very wide limits. Even within the individual states it does not remain the same. Thus far, however, the action of the government is alike not only throughout Prussia but in all parts of Germany. It prevents absolutely the treatment of any forest of this class under im-

provident or wasteful methods; nor does it allow any measure to be carried into effect which may deprive posterity of the enjoyment which it has a right to expect." * *

The relations of the State to the third class of forests, those belonging to private proprietors, are of a much less intimate nature. The basis of these relations is, however, the same. To quote again from Donner: "The duty of the State to sustain and further the well being of its citizens regarded as an imperishable whole, implies for the government the right and the duty to subject the management of all forests to its inspection and control." This intervention is to be carried, however, "only so far as may be necessary to obviate the dangers which an unrestrained utilization of the forest by its owners threatens to excite, and the rights of property are to be respected to the utmost consistency with such a result." Prussia, of all the German countries, has respected these rights most highly, and the government exerts practically no restraining influence except where the evident results of deforestation would be seriously dangerous. Here it may and does guard most zealously the wood lands, whose presence is a necessary safeguard against certain of the more destructive phenomena of nature, and which have been called in general "protection forests". Of their many sided influence so much has been said and written of late in America—both truly and falsely—that no farther reference to the subject seems needful.

"The State leaves open a way of escape for the private proprietor who finds himself unwilling to suffer such restriction of his rights for the public good, and shows itself willing to buy up areas not only of protection forests but also of less vitally important wood lands. On the other hand, it is ready, with a broadness of view which the zeal of forest authorities sometimes unfortunately excludes, to give up to private ownership lands which, by reason of their soil and situation, will contribute better to the commonwealth under cultivation than as forest.

"In this way the forests whose preservation is most important are gradually passing into the hands of the State; yet the total area of the wood lands is increasing but slowly.

"The policy of State aid in the afforestation of waste lands important through their situation on high ground or otherwise is fully recognized (a notable example exists upon the Hohe Venn near Aix-la-Chapelle) but the absence of considerable mountain chains has given to this branch of government influ-

ence very much less prominence than in the Alps of Austria, Switzerland and France, where its advantages appear on a larger and more striking scale.

"In closing this brief sketch of forest policy in Prussia, you will perhaps allow me to refer for a moment to the erroneous ideas of German forest management which have crept into our literature. They have done so, I believe, partly through a desire of the advocates of forestry to prove too much, and they injure the cause of forestry, because they tend to make forest management ridiculous in the eyes of our citizens. The idea has risen that German methods are exaggeratedly artificial and complicated, and not unnaturally the inference has been made that forestry in itself is a thing for older and more densely populated countries, and that forest management is inapplicable and incapable of adaptation to the conditions under which we live. It is true, on the contrary, that the treatment of German forests is distinguished above all things by an elastic adaptability to circumstances, which is totally at variance with the iron-clad formality which a superficial observation may believe it sees. It is equally true that its methods could not be transported unchanged into our forests without entailing discouragement and failure, just as our method of lumbering would be disastrous there; but the principles which underlie not only German, but all rational forest management, are true all the world over. It was in accordance with them that the forests of British India were taken in hand and are now being successfully managed, but the methods into which the same principles have developed are as widely dissimilar as the countries in which they are being applied."

So forest management in America must be worked out along lines which the conditions of our life will prescribe. It never can be a technical imitation of that of any other country, and a knowledge of forestry abroad will be useful and necessary rather as matter for comparison than as a guide to be blindly obeyed. It must be suited not only to the peculiarities of our national character, but also to the climate, soil and timber of each locality, to the facilities for transportation, and relations of supply and demand, and the hundred other factors which go to make up the natural character of a hillside, a county or a state. Its details cannot be laid down *ex cathedra*, but must spring from a thorough acquaintance with the theory of forestry, combined with exhaustive knowledge of local conditions. It will necessarily lose the formality and minuteness

which it has acquired in countries of older and denser settlement, and will take on the character of largness and efficiency which has placed the methods of American lumbermen, in their own sphere, far beyond all competitors.

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
162	Sept., 1875	Geol. Survey...	Streptelasma corniculum Hall	1
207	1875	"	Streptelasma corniculum Hall	1
231	Oct., 1875	"	Orthis testudinaria var. meeki Miller	1
236	Oct., 1875	" ...	Orthis testudinaria var. meeki Miller	1
263	Sept., 1875	"	Schizotreta pelopea Billings	1
272	Oct., 1875	"	Orthis testudinaria var. meeki Miller	Indef.
273	"	"	Orthis (Dinorthis) proavita W. and S	1
274	"	"	Orthis (Dinorthis) subquadrata Hall	Indef.
278	"	"	Orthis (Dinorthis) proavita W. and S	2
279	"	"	Orthis subæquata var. circularis Winchell	3
294	Sept., 1875	"	Climacograptus typicalis Hall	1
295	Sept., 1875	"	Climacograptus typicalis Hall	1
302	1875	"	Diplograptus putillus Hall	1
318	Oct., 1875	"	Streptelasma corniculum Hall	1
321	Oct., 1875	"	Orthis subæquata Conrad	2
346	1872	"	Orthis subæquata var. circularis Winchell	3
364	Oct., 1872	"	Streptelasma corniculum Hall	1
390	Oct., 1872	"	Climacograptus typicalis Hall	1
396	Oct., 1875	"	Orthis (Dinorthis) subquadrata Hall	2
433	Oct., 1875	" . .	Streptelasma profundum Hall	2
651	Aug. 1875	"	Orthis subæquata var conradi Winchell	1
664	Aug., 1877	"	Streptelasma profundum Hall	1
672	"	"	Orthis (Dinorthis) deflecta Conrad	3
707	"	" ..	Orthis (Dalmanella) subæquata Conrad	3
710	"	"	Streptelasma profundum Hall	1
712	"	"	Rauffella filosa Ulrich	1
713	"	"	Rauffella filosa Ulrich	2
720	"	"	Orthis (Dalmanella) subæquata Conrad	2
734	"	"	Rhynchonella ainsliei Winchell	9
753	"	"	Orthis subæquata var. conradi Winchell	5
766	"	"	Orthis (Dalmanella) subæquata Conrad	Indef.
3487	1879	"	Streptelasma profundum Hall	"
3488	1879	"	Streptelasma profundum Hall	"
3489	1879	"	Streptelasma profundum Hall	"
3491	1879	"	Rauffella filosa Ulrich	1
3493	1879	"	Rhynchonella capax Conrad	2
3504	May, 1879	"	Lingula coboursensis Billings	1
3513	Aug., 1877	"	Orthis subæquata Conrad	2
3515	April, 1879	"	Orthis subæquata var. circularis Winchell	2
4031	Sept., 1880	"	Rhynchonella ainsliei Winchell	9
4032	"	"	Orthis (Dalmanella) subæquata Conrad	Indef.
4034	"	"	Orthis tricenaria Conrad	"
4035	"	"	Orthis (Dalmanella) testudinaria Conrad	2
4038	"	"	Streptelasma profundum Hall	1
4042	"	"	Crania setigera Hall	1
4049	"	"	Orthis subæquata var. circularis Winchell	Indef.
4053	"	"	Rhynchonella capax Conrad	1
4055	"	"	Orthis (Dinorthis) meedsi W. and S	Indef.
4056	"	"	Orthis (Dalmanella) subæquata Conrad	"
4057	"	"	Streptelasma profundum Hall	"
4061	"	"	Rhaphistoma lenticularis Conrad	"
4076	"	"	Orthis (Dinorthis) subquadrata Hall	"
4078	"	"	Orthis testudinaria var. meeki	"
4079	"	"	Orthis (Dinorthis) subquadrata Hall	"
4081	"	"	Hindia sphæroidalis Duncan	17
4085	"	"	" " "	4
4092	"	"	Rhynchonella capax Conrad	6
4094	"	"	Orthis (Plectorthis) whitfieldi Winchell	1
4097	"	"	Diplograptus putillus Hall	1
4935	1882	"	Orthis subæquata var. circularis Winchell	13
4944	1882	Presented	Receptaculites oweni Hall	3
4946	1882	"	Rauffella filosa Ulrich	2
4948	1882	"	Platystrophia biforata Schlotheim	1
4999	1882	Geol. Survey...	Rhynchonella capax Conrad	10
5001	1882	"	Orthis (Dinorthis) pectinella var. sweeneyi Winchell	2
5053	1882	Presented	Streptelasma profundum Hall	6
5079	1876-1879	Geol. Survey...	Streptelasma profundum Hall	9
5148	1881	Presented	Orthis subæquata var. perveta Conrad	1
5149	1881	"	Orthis subæquata var. circularis Winchell	1
5305	Aug., 1883	"	Streptelasma profundum Hall	5
5307	"	"	Platystrophia biforata Schlotheim	1
5476	Aug., 1877	Geol. Survey...	Rhynchonella capax Conrad	9
5478	"	" ...	" " "	4
5479	"	" ...	" " "	1

ADDITIONS.

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Sec.17, Rochester, Olmsted Co., Minn.	Galena	M. W. Harrington (Garrick's quarry)
" " " "	"	" "
Spring Valley, Minn	Cincinnati	N. H. Winchell.
" "	"	"
Mantorville, Minn	Galena	M. W. Harrington.
Spring Valley, Minn	Cincinnati	N. H. Winchell.
" "	"	"
" "	"	"
" "	"	"
Minneapolis, Minn	Trenton	"
Mantorville, Minn	Galena	M. W. Harrington.
" "	"	
Forestville, Minn	Maquoketa?	N. H. Winchell.
Minneapolis, Minn	Trenton	"
" "	Hudson River	"
Rochester, Minn	Trenton	"
Near Rochester, Minn.	Galena	"
Mantorville, Minn	"	"
Spring Valley, Minn	Cincinnati	"
Chatfield, Minn	Trenton	"
Fountain, Minn	"	"
Pleasant Grove, Minn	"	"
Minneapolis, Minn	"	C. L. Herrick.
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
Near Cannon Falls, Minn	"	N. H. Winchell.
" " "	"	"
" " "	"	"
" " "	"	"
" " "	"	"
Minneapolis, Minn	"	H. V. Winchell.
" "	"	C. L. Herrick.
Oxford Mills, Goodhue county	"	N. H. Winchell.
Near Lanesboro, Minn	"	"
" " "	"	"
" "	"	"
" "	"	"
" "	"	"
Lanesboro, Minn	"	"
Near Fountain, Minn	"	"
" " "	"	"
" " "	Galena	"
" " "	"	"
" " "	Trenton	"
" " "	"	"
Spring Valley, Minn	Cincinnati	"
" "	"	"
" "	"	"
" "	Niagara	"
" "	"	"
" "		"
" "	Cincinnati	"
" "		"
State St., East Minneapolis	Hudson River	"
Near Marion, Minn	" "	Cora E. Goode
" " "	Trenton	"
" " "	"	"
Mineola, Goodhue county, Minn	"	N. H. Winchell.
" " " "	"	"
Minneapolis, Minn	"	H. V. Winchell.
" "	"	C. L. Herrick.
" "	"	J. O. Kassube.
" "	"	"
Cannon Falls, Minn	"	W. H. Scofield.
" "	"	"
Minneapolis, Minn	Green shale	C. L. Herrick.
" "	"	"
" "	"	"

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
5480	Aug., 1877	Geol. Survey...	Rhynchonella ainsliei Winchell.....	31
5481	“	“	Rhynchonella capax Conrad..............	12
5483	“	“ ...	“ “ “	17
5484	“	“	Rhynchonella ainsliei Winchell..........	10
5485	1879	“	Rhynchonella capax Conrad..............	4
5488	1879	“	“ “ “	14
5489	1879	“ ...	Rhynchonella ainsliei Winchell..........	3
5490	1879	“	Rhynchonella capax Conrad..............	1
5491	1879	“	“ “ “	3
5492	1879	“	Rhynchonella ainsliei Winchell..........	4
5493	1879	“	Rhynchonella capax Conrad..............	6
5495	Sept., 1880	“ ...	“ “ “	2
5496	“	“ ...	“ “ “	3
5497	“	“	“ “ “	3
5498	“	“	Rhynchonella ainsliei Winchell..........	1
5500	“	“	Crania setigera Hall..............	2
5505	“	“	Rhynchonella ainsliei Winchell..........	2
5506	“	“	Rhynchonella capax Conrad..............	1
5508	“	“	“ “ “	12
5509	“	“	“ “ “	4
5512	“	“	Rhynchonella ainsliei Winchell..........	3
5513	“	“	Rhynchonella capax Conrad..............	1
5515	“	“	“ “ “	4
5516	“	“	“ “ “	1
5517	“	“	Rhynchonella ainsliei Winchell..........	1
5518	1873	“ ...	Rhynchonella capax Conrad..............	2
5519	1880	“	“ “ “	5
5521	1880	“	Rhynchonella ainsliei Winchell..........	1
5522	1880	“	Rhynchonella capax Conrad..............	1
5547	1880	“	Rhynchonella perlamellosa Whitfield..........	4
5548	1880	“	Platystrophia biforata var. crassa James..........	1
5668	1884	Purchase.......	Lingula elderi Whitfield..............	1
5839	May, 1885	Geol. Survey...	Ischadites iowensis Owen..............	1
5840	“	“	Streptelasma corniculum Hall..............	9
5848	“	“	Rhaphistoma lenticularis Sowerby..........	7
5852	“	“ ..	Rhynchonella capax Conrad..............	12
5856	“	“	Orthis (Dalmanella) testudinaria..........	2
5860	“	“	Orthis meedsi W. and S..............	4
5861	“	“ ...	“ “ “	2
5862	“	“	Platystrophia biforata Schlotheim..........	2
5865	“	“	Cryptozoon minnesotense Winchell..........	Indef.
6670	Sept., 1885	“	Orthis remnicha Winchell..............	7
6758	June, 1888	“	Receptaculites oweni Hall..............	1
6760	“	“	Ischadites iowensis Owen..............	3
6774	Sept., 1888	“	Streptelasma profundum Hall..............	1
6775	“	“	Orthis (Dalmanella) subæquata Conrad..........	1
6801	“	“	“ “ “ “	2
6802	“	“	Orthis tricenaria Conrad..............	3
6803	“	“	Orthis (Dalmanella) subæquata Conrad..........	1
6804	“	“	Orthis subæquata var. circularis Winchell..........	2
6805	“	“ ...	Orthis..............	[illegible]
6806	“	“ ...	Orthis (Dalmanella) testudinaria Dalman..........	3
6808	“	“ ..	Streptelasma profundum Hall..............	1
6828	Jan., 1889	“	Rusted, coarse, quartz sand..............	Indef.
6829	“	“	Gray siliceous shale, or “slate”..........	
6830	“	“	White sand, with some yellowish shale..........	
6831	“	“	Fine white sand, giving first water..........	
6832	“	“	Green shale..............	
6833	“	“	Fine white sand, with globules of pyrites..........	“
6834	“	“	Green shale or sand, with some white sand..........	“
6835	“	“	White sand with some specks of green sand..........	“
6836	“	“ ...	Mainly white sand, of a grayish aspect..........	“
6837	“	“	Quartz sand, with some gray grains, all rounded.....	“
6838	“	“	Rounded white sand, with some gray grains & pyrites	“
6839	“	“	Gray shale, slightly greenish..........	“
6840	“	“	White sand, with some fragments..........	“
6841	“	“	White sand, rounded..............	“
6842	“	“	Shale or clay, with quartz sand..........	“
6843	“	“	Coarse quartz sand, almost pebbly..........	“
6844	“	“	The same. Here the water all ran out..........	“
6845	“	“	Red slate or shale, with white kaolinitic grains..........	“
6846	“	“	White sand, with reddish grains and shale pieces.....	“
6847	“	“	Red clay (shale) unwashed, hardened in drying..........	
6848	“	“	Dark red, or brown feldspathic sandstone..........	

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Minneapolis, Minn	Green shale	C. L. Herrick.
" "	"	"
Fountain, Minn.	"	N. H. Winchell.
Minneapolis, Minn	"	C. L. Herrick.
Near Cannon Falls, Minn	Hudson River	N. H. Winchell.
" " "	"	"
Minneapolis, Minn	Green shale	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
Near Lanesboro, Minn	"	"
" " "	"	"
" " "	"	"
" " "	"	"
Near Fountain, Minn	"	"
" " "	"	"
" " "	"	"
" " "	"	"
" " "	"	"
Minneapolis, Minn	"	"
Holden, Goodhue Co., Minn	"	"
Kenyon, Goodhue Co., Minn	"	"
Minneapolis, Minn	"	Chas. Kassube.
" "	"	"
" "	"	N. H. Winchell.
" "	"	H. V. Winchell.
Near Lanesboro, Minn	"	N. H. Winchell.
" " "	"	"
Spring Valley, Minn	Trenton	"
" " "	Cincinnati	"
Minneapolis, Minn	Trenton	Wm. Bowling.
Cannon Falls, Minn	Galena	N. H. Winchell.
" "	"	"
" "	"	"
" "	Trenton	"
" "	Galena	"
" "	"	"
" "	"	"
" "	"	"
" "	Shakopee	"
Red Wing, Minn		"
Holden, Minn	Galena	"
" "	"	"
Minneapolis, Minn	Trenton	"
" "	"	"
St. Paul, Minn	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
Stillwater, Minn	Drillings from	N. H. Winchell, taken at 18 feet.
" "	Stillwater	" " 103 "
" "	deep well.	" " 142 "
" "	"	" " 162 "
" "	"	" " 203 "
" "	"	" " 215 "
" "	"	" " 271 "
" "	"	" " 302 "
" "	"	" " 312 "
" "	"	" " 322 "
" "	"	" " 349 "
" "	"	" " 380 "
" "	"	" " 450 "
" "	"	" " 460 "
" "	"	" " 540 "
" "	"	" " 630 "
" "	"	" " 688 "
" "	"	" " 701 "
" "	"	" " 706 "
" "	"	" " 717 "
" "	"	" " 796 "

• MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained.		Name.	Number of specimens
	When.	Whence.		
6849	Jany., 1889	Geol. Survey...	Dark red, or brown feldspathic sandrock	Indef.
6850	"	"	Somewhat darker, otherwise same as last.............	"
6851	"	"	Same as last..	"
6852	"	"	Same as last..	"
6870	April, 1889	Presented	Gold bearing quartz	4
6871	"	"	" " "	3
6872	"	"	" " "	2
6873	"	"	" " "	2
6874	"	"	Granite containing garnets................................	1
6875	"	"	Potsdam sandstone..	1
6876	"	"	"Cosmic material"...	4
6877	"	Geol. Survey...	Selenite..	Indef.
6879	June, 1889	"	Yellowish blue pebbly clay................................	"
6880	"	"	Slightly darker pebbly clay................................	"
6881	"	"	Same as 6880..	"
6882	"	"	" "	"
6883	"	"	" "	"
6884	"	"	" "	"
6885	"	"	Gravel and sand bearing gas..............................	"
6886	"	"	Same as 6880, pebbly clay................................	"
6887	"	"	" " " "	"
6888	"	"	" " " "	"
6889	"	"	" " " "	"
6890	"	"	" " " "	"
6891	"	"	Drift gravel and sand with fragments of lignite......	"
6892	"	"	Drift gravel & sand with fragments of gray limestone.	"
6893	"	"	Fine quicksand..	"
6894	"	"	Magnesian limestone......................................	"
6895	"	"	Magnesian limestone drillings	"
6896	"	"	Gray limestone..	"
6897	"	"	Same as last, but with some drift.......................	"
6898	"	"	Same as last..	"
6899	"	"	Coarse drift pebbles......................................	"
6900	"	"	Dolomitic limestone......................................	"
6901	"	"	Same as last, but nearly white..........................	"
6902	"	"	Gray aluminous limestone................................	"
6903	"	"	Gray limestone	"
6904	"	"	" "	"
6905	"	"	" "	"
6906	"	"	" "	"
6907	"	"	" "	"
6908	"	"	Gray limestone, finely crystalline........................	"
6909	"	"	Gray limestone, with siliceous grains...................	"
6910	"	"	Gray limestone..	"
6911	"	"	" "	"
6912	"	"	" "	"
6913	"	"	Gray shale, with quick effervescence	"
6914	"	"	Gray limestone..	"
6915	"	"	Bluish gray shale; slight effervescence................	"
6916	"	"	Bluish gray shale; pebbly................................	"
6917	"	"	Fine bluish shale...	"
6918	"	"	Coarser shale..	"
6919	"	"	Fine homogeneous gray shale............................	"
6920	"	"	Blue and gray shale and limestone......................	"
6921	"	"	Same as last	"
6922	"	"	Fine bluish gray shale.....................................	"
6923	"	"	Blue shale..	"
6924	"	"	White sandstone...	"
6925	"	"	" "	"
6926	"	"	" "	"
6927	"	"	White, fine sand...	"
6928	"	"	Magnesian limestone	"
6929	"	"	White sandstone...	"
6930	"	"	Magnesian limestone	"
6931	"	"	Mottled green and reddish shale........................	"
6932	"	"	Green shale and magnesian limestone	"
6933	"	"	Mainly magnesian limestone..............................	"
6934	"	"	Much like last, but more siliceous	"
6935	Aug., 1889	"	Yellow loam, or clay.......................................	"
6936	"	"	Yellow clay—lacustrine...................................	"
6937	"	"	Very fine lacustrine blue clay............................	"
6938	"	"	Drift gravel with some clay...............................	"
6939	"	"	Drift gravel, much limestone	"
6940	"	"	Coarse drift gravel, much limestone	"

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Stillwater, Minn	Drillings from	N. H. Winchell, taken at 898 feet.
" "	Stillwater	" " 923 "
" "	deep well.	" " 952 "
" "	"	" " 2,250 "
Nova Scotia, Canada		Brookfield mine, Anderson, Douglas & Co.
" "		Neptune mine, " " "
" "		Malaga district, " " "
Salmon River, N. S.		From Prof J. S. Clark.
"Garnet Hill" N. H		From Prof. J. A. Dodge.
Port Henry, N. Y	Potsdam	From W. H. Benedict.
Nininger. Minn	?	From Ig. Donnelly.
Minneapolis, Minn		O. W. O. Contact of limestone and sandstone.
Freeborn, Minn	Drillings from	No. 1. depth 20 feet.
" "	Freeborn	" 2, " 30 "
" "	gas well.	" 3, " 40 "
" "	"	" 4, " 50 "
" "	"	" 5, " 60 "
" "	"	" 6, " 70 "
" "	"	" 7, " 74 "
" "	"	" 8, " 80 "
" "	"	" 9, " 90 "
" "	"	" 10, " 100 "
" "	"	" 11, " 110 "
" "	"	" 12, " 120 "
" "	"	" 13, " 130 "
" "	"	" 14, " 140 "
" "	"	" 15, " 145 "
" "	"	" 16, " 150 "
" "	"	" 17, " 160 "
" "	"	" 18, " 190 "
" "	"	" 19, " 200 "
" "	"	" 20, " 210 "
" "	"	" 21, " 220 "
" "	"	" 22, " 230 "
" "	"	" 23, " 240 "
" "	"	" 24, " 250 "
" "	"	" 25, " 260 "
" "	"	" 26, " 270 "
" "	"	" 27, " 280 "
" "	"	" 28, " 290 "
" "	"	" 29, " 300 "
" "	"	" 30, " 310 "
" "	"	" 31, " 320 "
" "	"	" 32, " 330 "
" "	"	" 33, " 340 "
" "	"	" 34, " 350 "
" "	"	" 35, " 360 "
" "	"	" 36, " 370 "
" "	"	" 37, " 380 "
" "	"	" 38, " 390 "
" "	"	" 39, " 400 "
" "	"	" 40, " 410 "
" "	"	" 41, " 420 "
" "	"	" 42, " 430 "
" "	"	" 43, " 440 "
" "	"	" 44, " 450 "
" "	"	" 45, " 460 "
" "	"	" 46, " 470 "
" "	"	" 47, " 480 "
" "	"	" 48, " 490 "
" "	"	" 52, " 535 "
" "	"	" 53, " 710 "
" "	"	" 54, " 840 "
" "	"	" 55, " 880 "
" "	"	" 56, " 900 "
" "	"	" 57, " 920 "
" "	"	" 58, " 930 "
" "	"	" 59, " 960 "
Moorhead, Minn	Drillings from	" 2, " 5 "
" "	Moorhead	" 3, " 55 "
" "	well.	" 4, " 110 "
" "	"	" 5, " 115 "
" "	"	" 6, " 125 "
" "	"	" 7, " 135 "

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained.		Name.	Number of specimens
	When.	Whence.		
6941	Aug., 1889	Geol. Survey...	Drift gravel and sand	Indef.
6942	"	"	Sandy and gravelly clay	"
6943	"	"	Sandy clay—blue	"
6944	"	"	" " "	"
6945	"	"	Gravelly and sandy clay	"
6946	"	"	Boulder; hard gray gneiss	"
6947	"	"	Boulder; quartzose	"
6948	"	"	Bluish, sandy clay	"
6949	"	"	" "	"
6950	"	"	Quicksand	"
6951	"	"	Quicksand, with some clay	"
6952	"	"	Green shale or clay	"
6953	"	"	Soft reddish chlorite-granite or gneiss	"
6954	"	"	" " "	"
6955	"	"	" " "	"
6956	"	"	" " "	"
6957	"	"	" " "	"
6958	"	"	The same, but more like 6946	"
6959	"	"	Same, but more green from chlorite	"
6960	"	"	" " "	"
6961	"	"	" " "	"
6962	"	"	Same, but finer	"
6963	"	"	Same, but coarser	"
6964	"	"	Same, but darker colored	"
6965	"	"	Same, fine drillings	"
6966	"	"	" "	"
6967	"	"	Soft, greenish, red-mottled felsyte	"
6968	"	"	Same, with some calcite	"
6969	"	"	Mainly water-worn sand	"
6970	"	"	Mixed granitic rock	"
6971	"	"	Mainly light chloritic granite	"
6972	"	"	Mostly white feldspar and quartz	"
6973	"	"	Brownish-red rock	"
6974	"	"	Gray, epidotic, finely granular gabbro	"
6975	"	"	Same as 6974	"
6976	"	"	"	"
6977	"	"	Apparently the same, but finer	"
6978	"	"	Essentially quartzose	"
6979	"	"	Same as 6978; pyritiferous	"
6980	"	"	Drillings; gray, pulverulent	"
6981	"	"	Drillings brown, fine-grained	"
6982	"	"	Essentially a brown felsyte	"
6983	"	"	Conglomerate with brown felsyte	"
6984	"	"	Pink and gray conglomerate and quartzyte	"
6985	"	"	Granular white quartz	"
6986	"	"	Same, a granular quartzyte	"
6987	"	"	Same, but showing gray also	"
6988	"	"	Same, but more gray, also pink	"
6989	"	"	" " " " "	"
6990	"	"	Dark gray, pulverulent; similar to 6980	"
6991	"	"	Trap-rock, epidotic diabase	"
6992	"	"	Gray diabasic trap-rock	"
6993	"	"	" " "	"
6994	"	"	Apparently the same, very fine	"
6995	"	"	Brown-gray diabasic rock	"
6996	"	"	Drillings of two sorts	"
6997	"	"	"Black slate" or argillyte	"
6998	"	"	" " "	"
6999	"	"	Same, but with a greenish tinge	"
7000	"	"	Same as 6998	"
7001	"	"	Same as 6999	"
7002	"	"	Essentially the same, not so slaty	"
7003	"	"	Same, rather light gray	"
7004	"	"	Gray slate, slightly pyritiferous	"
7005	"	"	" " "	"
7006	"	"	Drillings of two kinds	"
7007	"	"	Drillings very fine, light yellowish	"
7008	"	"	" " " " "	"
7009	"	"	" " " " "	"
7010	"	"	Same as last, but also some of the next	"
7011	"	"	Gray, compact, fine, diabasic rock	"
7012	"	"	Same as 7011, with some gray slate	"
7013	"	"	Same as 7011	"
7014	"	"	Same, gray rock predominates	"

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Moorhead, Minn.	Drillings from Moorhead well.	No. 8, Depth 145 feet.
" "		" 9, " 155 "
" "		" 10, " 165 "
" "	"	" 11, " 185 "
" "	"	" 12, " 195 "
" "	"	" 13, " 200 "
" "	"	" 14, " 220 "
" "	"	" 15, " 240 "
" "	"	" 16, " 300 "
" "	"	" 17, " 345 "
" "	"	" 18, " 360 "
" "	"	" 19, " 375 "
" "	"	" 21, " 400 "
" "	"	" 23, " 475 "
" "	"	" 24, " 600 "
" "	"	" 25, " 635 "
" "	"	" 26, " 745 "
" "	"	" 27, " 765 "
" "	"	" 28, " 800 "
" "	"	" 29, " 900 "
" "	"	" 30, " 1,000 "
" "	"	" 31, " 1,010 "
" "	"	" 32, " 1,050 "
" "	"	" 33, " 1,065 "
" "	"	" 34, " 1,090 "
" "	"	" 35, " 1,120 "
" "	"	" 36, " 1,195 "
" "	"	" 37, " 1,205 "
" "	"	" 38, " 1,265 "
" "	"	" 39, " 1,290 "
" "	"	" 40, " 1,325 "
" "	"	" 41, " 1,425 "
Duluth, Minn.	Drillings from Duluth deep well.	" 3, " 243 "
" "		" 4, " 276 "
" "		" 6, " 417 "
" "	"	" 7, " 448 "
" "	"	" 8, " 463 "
" "	"	" 9, " 468 "
" "	"	" 10, " 473 "
" "	"	" 11, " 490 "
" "	"	" 12, " 506 "
" "	"	" 13, " 508 "
" "	"	" 14, " 511 "
" "	"	" 15, " 513 "
" "	"	" 16, " 514 "
" "	"	" 17, " 516 "
" "	"	" 18, " 520 "
" "	"	" 19, " 524 "
" "	"	" 20, " 528 "
" "	"	" 21, " 530 "
" "	"	" 22, " 554 "
" "	"	" 23, " 574 "
" "	"	" 24, " 590 "
" "	"	" 25, " 598 "
" "	"	" 26, " 613 "
" "	"	" 27, " 619 "
" "	"	" 28, " 680 "
" "	"	" 29, " 880 "
" "	"	" 30, " 1,080 "
" "	"	" 32, " 1,175 "
" "	"	" 33, " 1,235 "
" "	"	" 34, " 1,340 "
" "	"	" 35, " 1,370 "
" "	"	" 36, " 1,375 "
" "	"	" 37, " 1,400 "
" "	"	" 38, " 1,435 "
" "	"	" 39, " 1,437 "
" "	"	" 40, " 1,445 "
" "	"	" 41, " 1,448 "
" "	"	" 42, " 1,450 "
" "	"	" 43, " 1,452 "
" "	"	" 44, " 1,454 "
" "	"	" 45, " 1,455 "
" "	"	" 46, " 1,456 "

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7015	Aug., 1889	Geol. Survey...	Same, gray rock predominates	Indef.
7016	"	"	Same, but lighter colored	"
7017	"	" ..	" " "	"
7018	"	"	Gray quartzyte, very fine; same as 7014	"
7019	"	"	" " " "	"
7020	"	"	Same, but more cleavable	"
7021	"	"	Same gray rock, slaty	"
7022	Jan'y, 1890	Exchange	Spirifer pennatus Owen	2
7023	"	"	Spirifer keokuk var.	3
7024	"	"	Spirifer cameratus Morton	2
7025	"	"	Spirifer mucronatus Conrad	5
7026	"	"	Spirifer whitneyi Hall	4
7027	"	"	Spirifer hungerfordi Hall	16
7028	"	"	Spirifer orestes Hall and Whitfield	3
7029	"	"	Orthis impressa Hall	7
7030	"	"	Atrypa hystrix Hall	2
7031	"	"	Atrypa reticularis Linn	13
7032	"	"	" " "	3
7033	"	"	Atrypa aspera Schloth	3
7034	"	"	Rhynchonella alta Calvin	10
7035	"	"	Rhynchonella capax Conrad	3
7036	"	"	Athyris ambigua Sowerby	6
7037	"	"	Athyris subtilita Hall	4
7038	"	"	Productus costatus Sowerby	3
7039	"	"	Hemipronites crassus Meek and Worthen	7
7051	"	"	Zaphrentis spinulifera Hall	1
7964	"	"	Blue limestone	1
7065	Feb'y, 1890	"	Apophyllite	1
7066	"	"	Iron, apophyllite and other minerals	1
7067	"	"	Chacopyrite and pyrite	1
7068	"	"	Pyrite on calcite	1
7069	"	"	Magnetite (crystals)	1
7070	"	"	Calcite and apophyllite	1
7071	"	"	Byssolitic calcite	1
7072	"	"	Pink orthoclase	1
7073	"	"	Pyroxene	1
7074	"	"	Sphalerite	1
7075	Ma'ch, 1890	Presented	Graphite	1
7076	"	"	Concretions in slate	3
7077	"	"	Kaoline	Indef.
7078	"	"	Lignite	"
7079	"	"	Asaphus canadensis Chapm	2
7081	1876	"	Fossil bones from S. America	Indef.
7082	June, 1890	"	Pyroxenite var. "Websterite" 1st type	1
7083	"	"	Pyroxenite var. "Websterite" 2d type	1
7084	"	"	Coquina	2
7085	"	"	Asbestos. artificial	Indef.
7086	"	Exchange	Limestone, No. 1	2
7087	"	"	" (above No. 1) No. 2	2
7088	"	"	" No. 3	1
7089	"	"	" No. 4	1
7090	"	"	"	1
7091	"	"	"	1
7092	"	"	Marshall sandstone	2
7093	"	"	Limestone	2
7094	"	"	Conglomerate	2
7095	"	"	Green mica	2
7096	"	"	Feldspar	1
7097	"	"	Magnetite in granite	7
7098	"	"	Selenite	8
7099	"	"	Pyrite	15
7100	"	"	Calcite and pyrite	6
7101	"	"	Calcite	12
7102	"	"	Brown calcite crystals	15
7103	"	"	Stalactites	2
7104	"	"	Stalagmites	3
7105	"	"	Cyathophyllum	7
7106	"	Presented	Deposits from Mammoth Hot Springs	Indef.
7107	"	"	Limestone with barnacles attached	3
7108	"	"	Cinnabar	1
7109	"	"	Cinnabar crystals and some native quicksilver	1
7110	"	"	Vein rock with cinnabar	1
7111	"	"	Vein rock, barren (gangue)	1
7112	"	"	Foot wall rock (serpentine)	1

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Duluth, Minn	Drillings from Duluth deep well.	No. 47, Depth 1,457 feet.
" "		" 48, " 1,468 "
" "		" 49, " 1,477 "
" "	"	" 50, " 1,487 "
" "	"	" 51, " 1,495 "
" "	"	" 52, " 1,500 "
" "	"	" 53, " 1,507½ "
Independence, Iowa	Hamilton	C. W. Irish, Iowa City, Iowa.
Pella, Iowa	Sub. Carb	" " "
Madison Co., Iowa	Upper Carb	" " "
Widdler, Canada	Hamilton	" " "
Rockford, Iowa	Chemung	" " "
" "	"	" " "
" "	"	" " "
" "	"	" " "
" "	"	" " "
" "	"	" " "
Independence; Iowa	Hamilton	" " "
" "	"	" " "
Solon, Iowa	"	" " "
Fillmore Co., Minn	Trenton	" " "
Pella, Iowa	Sub. Carb	" " "
Madison Co., Iowa	Upper Carb	" " "
" "	"	" " "
" "	"	" " "
Pella, Iowa	Sub. Carb	. " "
Iowa City, Iowa	Hamilton	" " "
St. Peters, Chester Co., Pa		J. Eyerman, Easton, Pa.
" " "		" " "
" " "		" " " [French Creek mines
" " "		" " "
" " "		" " "
" " "		" " "
" " "		" " "
" " "		" " "
" " "		" " "
Friedensville, Shegle Co., Pa		" " " [Uberroth mine.
Town 64-6, S. E. ¼ Sec. 18		J. G. Emery.
Beaver Mine, Ont., Can		J. W. Bist, 328 Oak st., Minneapolis.
Blaine Twp., Anoka Co		H. V. Rumohe.
Big Fork, Ont., Can		Stanley Newton, 12 miles bel. Big Falls, Big Fork
Fields Crossing, Ont	Utica slate	A. W. Vogdes (Georgian Bay.)
South America		P. D. McMillan.
Balto Co., Md		G. H. Williams.
" "		"
St. Augustine, Fla		Mrs N. H. Winchell. [Science Hall.
		N. H. Winchell. (packing round steam pipes)
Grand Rapids, Mich	Sub. Carb	C. A Whittemore.
" "	"	" above No. 7086.
" "	"	" 2 feet deep.
" "	"	" 3 feet deep.
" "	"	" ¼ mile N. E. of No. 7086.
" "	"	" showing penetration of iron oxide.
West of Grand Rapids, Mich	"	" above the limestone. [crystals.
Grand Rapids, Mich	"	" lining of cavity cells in place of
" "	Drift	" fossiliferous.
Brunswick, Maine		"
" "		"
Topsham. Maine		"
Grand Rapids, Mich		"
		"
		" Myrtle st. quarry.
Grand Rapids, Mich		From C. A. Whittemore.
" " "		" "
" " "		" " 25 yrs. growth, cellar.
" " "		" " " " "
" " "		" "
Yellowstone Park		J. B. Alexander.
Port Clinton. Puget Sound		"
New Almaden, Cal.		The Quicksilver Mining Company.
" "		" " "
" "		" " "
" "		" " "
" "		" " "

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7113	June, 1890	Presented	Hanging wall rock (alta)	1
7114	"	Geol. Survey	Hinckley sandstone	5
7115	July, 1890	"	Jaspilyte pebble	1
7116	"	"	Kidney iron ore	1
7117	"	"	Gray granite drillings	Indef.
7118	"	"	Pyrites	1
7119	"	"	Inyo marble (dolomite)	1
7120	Aug., 1890	Exchange	Silicified wood	1
7121	"	"	Pectolite (massive)	1
7122	"	"	Garnet in mica schist	1
7123	"	"	Syenite	1
7124	"	"	Granite	1
7125	"	"	Garnet in mica schist	1
7126	"	"	White marble	1
7127	"	"	Trachyte	1
7128	"	"	Limestone	1
7129	"	"	Granite	1
7130	"	"	Chalcedony	5
7131	"	"	"	1
7132	"	"	"	1
7133	"	"	Colemanite (borate of lime)	3
7134	"	"	Sulphur (massive)	1
7135	"	"	Roscœlite (on quartz)	1
7136	"	"	Dye stuff, used for painting canoes and coloring tapa	1
7137	"	"	Chrysolite	Indef.
7138	"	"	Asbestos	"
7139	"	"	Ulexite (borate of lime)	1
7140	"	"	Volcanic ash or "White Lava"	1
7141	"	"	Syenitic granite	1
7142	"	"	Volcanic ash (indurated)	2
7143	"	"	Selenite	2
7144	"	"	Calcite	1
7145	"	"	Obsidian	2
7146	"	"	Halite	1
7147	"	"	Actinolite	1
7148	"	"	Feldspar	1
7149	"	"	Selenium (rare)	1
7150	"	"	Fuchsite	1
7151	"	"	Gneiss	1
7152	"	"	Colton marble	1
7153	"	"	Linarite (rare)	3
7154	"	"	Porphyritic diorite	3
7155	"	"	Gneiss, wall rock of Stonewall mine	1
7156	"	"	Core of diamond drill	1
7157	"	"	Quartz	1
7158	"	"	"Slickensides"	1
7159	"	"	Jasper	4
7160	"	"	Porphyry	1
7161	"	"	Hanging and foot wall of Nevada City mine	1
7162	"	"	Rock specimen, the deepest working of Comstock lode	1
7163	"	"	Syenite	1
7164	"	"	Steatite (soapstone)	1
7165	"	"	Diorite (used for paving)	1
7166	"	"	Ione red sandstone	1
7167	"	"	Granite	1
7168	"	"	Gold quartz	1
7169	"	"	Quartz and pyrite	1
7170	"	"	San Jose yellow sandstone	1
7171	"	"	Aragonite	1
7172	"	"	Wollastonite	1
7173	"	"	Altered serpentine and bronzite	1
7174	"	"	Gold quartz (Soulsby Mine)	1
7175	"	"	Halotrichite	Indef.
7176	"	"	Talcose slate, hard	1
7177	"	"	Hornblende	1
7178	"	"	Sample of foot and hanging wall rock	1
7179	"	"	Rock samples	3
7180	"	"	"	1
7181	"	"	"	1
7182	"	"	"	2
7183	"	"	"	3
1784	"	"	Foot wall of Nevada City Mine	1
1785	"	"	Stalactite (Clough's cave)	3
1786	"	"	Quartz with galenite and pyrite	1

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
New Almaden, Cal		The Quicksilver Mining Company.
Hinckley, Minn		N. H. Winchell.
Arlington street, Minneapolis	Drift	N. H. Winchell.
" " "	"	N. H. Winchell.
LeMars, Iowa		J. E. Todd, from near 1,400 feet down.
Near Porter, Minn		J. F. Fries.
California		California State Mining Bureau, No. 19
Sonoma county, Cal		" " " " " 21
Tehama county, Cal		" " " " " 22
Stickeen River, Alaska		" " " " " 23
Kern county, Cal		" " " " " 24
Raymond, Fresno county, Cal		" " " " " 25
Reed Ranch, Marine county, Cal		" " " " " 26
Placer county, Cal		" " " " " 27
Waterloo Mt., Cal		" " " " " 28
Kern county, Cal		" " " " " 29
Oro Grand, San Bernardino Co., Cal.		" " " " " 30
Aurora, Nevada		" " " " " 31
Tuolumne county, Cal		" " " " " 32
Volcano, Amador county, Cal		" " " " " 33
Calico, San Bernardino, Co., Cal		" " " " " 34
Humboldt Co., Nev		Cal. St. Min'g Bu., (Rabbit Hole mine) " 35
California		" " " 36
Panipe Island, South Sea		" " " 37
Tuolumne Co., Cal		" " " 38
Shasta Co., Cal		" " " 39
Esmeralda Co., Nev		" " " 40
Volcano, Amador Co., Cal		" " " 41
Tuolumne Co., Cal		" " ('country r'ck' of Soulsby mn.) " 42
Mokelumne Hill, Calaveras Co., Cal.		" " " 43
Monterey Co., Cal		" " " 44
San Bernardino Co., Cal		" " " 45
Glass Mt., Napa Co., Cal		" " " 46
San Bernardino Co., Cal		" " " 47
Sonoma Co., Cal		" " " 48
Mariposa Co., Cal		" " " 49
Honduras		" " " 50
Arch Bend, Orange Co., Cal		" " " 51
Humboldt Co., Cal		" " " 52
Colton, San Bernardino Co., Cal.		" " " 53
Cerro Gordo, Inyo Co., Cal		" " " 54
Shasta Co., Cal.		" " " 55
San Diego Co., Cal		" " " 56
Pica Cañon, Los Angeles Co., Cal		" " (oil well No. 9) " 57
Sheep Ranch, Tuolumne Co., Cal		" " " 58
San Bernardino Co., Cal		" " " 59
California		" " " 60
Calico, San Bernardino Co., Cal		" " " 61
Nevada Co., Cal		" " " 62
Virginia City, Nev		" " " 63
Point St. Pedro, Cal		" " " 64
El Dorado Co., Cal		" " " 65
California		" " " 66
Ione, Amador Co, Cal		" " " 67
Loomis, Placer county, Cal		" " (Mtn. View mine) " 68
Fresno county, Cal		" " " 69
Los Angeles county, Cal		" " " 70
California		" " " 71
Suisun, Solano county, Cal		" " " 72
Del Norte county, Cal.		" " " 73
Santa Clara county, Cal		" " " 74
Tuolumne county, Cal		" " " 75
Alameda county, Cal		" "
Soulsbyville, Toulumne county, Cal.		" "
Tuolumne county, Cal		" "
Sonora, Toulumne county, Cal		" "
San Bernardino county, Cal		" " (Fenner)
Daggett, Cal		" "
Near Poverty Hill		" "
Colusa county, Cal		" "
Providence, San Bernardino Co., Cal.		" "
Nevada county, Cal		" "
Tulare county, Cal		" "
Los Angeles county, Cal		" "

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens.
7187	Aug., 1890	Exchange	Tourmaline schist....................................	1
7188	"	"	Slate....................................	1
7189	"	"	Trachyte....................................	1
7190	"	"	Basalt (porphyritic)....................................	2
7191	"	"	Quartz....................................	1
7192	"	"	"	3
7193	"	"	Picrolite and serpentine....................................	1
7194	"	"	Geysers....................................	3
7195	"	"	Mariposite, "Blue Jay"....................................	1
7196	"	"	Talcose rock	1
7197	"	"	Chalcedony....................................	4
7198	"	"	Dike rock....................................	1
7199	"	"	Contact between slate and greenstone....................................	1
7200	"	"	Hanging wall, Amador Gold mine....................................	1
7201	"	"	Wall rock in Washington mine....................................	1
7202	"	"	Dike along "Mother Lode"....................................	2
7203	"	"	"Diorite"....................................	1
7204	"	"	Lava....................................	1
7205	"	"	Rock specimens....................................	5
7206	"	"	Agate....................................	1
7207	Sept., 1890	"	Borax crystals (artificial)....................................	1
7208	"	"	Hanksite....................................	1
7209	"	"	Ulexite (cotton balls)....................................	1
7210	"	"	Borax crystals (tincal)....................................	1
7211	"	"	Glauberite crystals....................................	6
7212	"	"	Orthoclase crystals....................................	4
7213	"	"	Borax crystals (tincal)	5
7214	"	"	Colemanite (borate of lime)....................................	1
7215	"	"	Arsenopyrite (mispickel)....................................	1
7216	"	"	Metallic antimony (native)....................................	1
7217	"	"	Stibiconite....................................	1
7218	"	"	Metacinnabarite....................................	1
7219	"	"	Cinnabar....................................	1
7220	"	"	"	1
7221	"	"	"	1
7222	"	"	" (in sandstone)....................................	1
7223	"	"	Calymene mammillata Hall (and others)....................................	1
7224	"	"	Murchisonia gracilis Hall (and others)....................................	2
7225	"	"	Diplograptus peosta Hall....................................	4
7226	"	"	Orthoceras sociale Hall....................................	16
7227	"	"	Tentaculites sterlingensis Meek and Worthen....................................	2
7228	"	"	Strophomena alternata Conrad....................................	2
7229	"	"	Receptaculites....................................	1
7230	"	"	Smithsonite....................................	1
7232	"	"	Bythotrephis succulens Hall....................................	1
7233	"	"	Sioux quartzyte....................................	2
7234	"	"	Garnets in schist....................................	2
7335	"	"	Hornblende schist....................................	1
7236	"	"	Talc....................................	1
7237	"	Presented......	Garnets in mica schist....................................	1
7238	"	Geol. Survey...	"Winnipeg" limestone....................................	1
7239	May, 1890	Purchased......	Meteoric stones....................................	Indef.
7240	April, 1890	"	Meteoric irons....................................	2
7241	Aug., 1890	"	Meteoric stones (chondritic)....................................	1
7242	Sept., 1890	Exchange	Pipe creek meteorite (chondrite)....................................	1
7243	....	Presented......	Quartz crystals....................................	1
7244	1891	"	Magnetic iron ore....................................	4
7245	1891	....	Staurolite....................................	1
7250	Apr., 1891	Geol. Survey...	Ischadites iowensis Owen....................................	1
7251	"	"	Receptaculites iowensis Hall....................................	1
7254	"	Exchange	Trigonocarpon triloculare Hildreth....................................	14
7255	"	"	Trigonocarpon hexacostatus....................................	1
7256	"	"	" "	1
7257	"	"	Rhabdocarpon....................................	2
7259	"	"	Parts of crinoid stems....................................	....
7260	1891	"	Selenite....................................	....
7262	1891	"	Phosphate rock: representing *redondite*....................................	1
7263	1891	"	Phosphate rock: representing *redondite*....................................	1
7264	1891	"	Phosphate rock: representing *redondite*....................................	5
7265	1891	"	Phosphate rock representing *renondite*....................................	6

ADDITIONS.—*Continued*.

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
San Benito county, Cal.		Calif. State Mining Bureau.
Calaveras, Cal.		" " "
San Luis Obispo, Cal.		" " "
Fresno county, Cal.		" " "
Mt. St. Helena, Napa county, Cal.		" " "
San Francisco, Cal.		" " "
El Dorado county, Cal.		" " "
Sonoma county, Cal.		" " "
California		" " " (Mother Lode.)
"		" " "
"		" " "
"		" " "
"		" " "
"		" " "
South Jackson, Cal.		" " "
California		" " " (Julian dists.)
Centerville, Cal.		" " "
Virginia, Nev.		" " " (C and C Shaft.)
Silver Peak, Nev.		" " "
Gila River, Ariz.		" " "
Central America		" " "
San Bernardino county, Cal.		Henry G. Hanks, San Francisco. No. 1
" "		" " " 2
Esmeralda county, Nev.		" " " 3
San Bernardino county, Cal.		" " " 4
" "		" " " 5
Maiden, Mont.		" " " 6
Esmeralda county, Nev.		" " " 7
San Bernardino county, Cal.		" " " 8
Tulare county, Cal.		" " " 9
Kern county, Cal.		" " " 10
Lander county, Nev.		" " " 11
Lake county, Cal.		" " " 12
" "		" " " 13
Sonoma county, Cal.		" " " 14
San Luis Obispo county, Cal.		" " " 15
Napa county, Cal.		" " " 16
Graf, Iowa	Trenton	F. W. Plapp, Dubuque, Iowa.
" "	"	" " "
" "	"	" " "
" "	Hudson River	" " "
" "	" "	" " "
Dubuque, Iowa	Trenton	" " "
" "	Gelena	" " "
" "		" " "
Grant county, Wis.	Trenton	" " "
Rowena, South Dak.		" " "
Hanover, N. H.		" " "
Olcott Falls, Vermont		" " "
Norwich, "		" " "
Alaska		A. L. Broughton.
Minneapolis, Minn.	Drift	Prof. N. H. Winchell.
Winnebago county, Iowa		N. H. and H. V. Winchell. Fell May 2, 1890.
Kiowa county, Kansas		N. H. Winchell—See Am. Geol., Vol. V., p. 309.
Washington county, Kansas		Fell June 25, 1890. [Y. Acad. Sci., 1889.
Bandera county, Texas		Dr. H. Hensoldt—See Vol. VIII, Trans., N.
Tower, Minn.	Keewatin	Capt. R. J. Williams, Breitung iron mine.
Cerro de Mercado, Mexico		Rev. J. A. Wright.
Pike Rapids, Mississippi River		
Wasioja, Dodge county Minn.	Galena	N. H. Winchell.
" " "		"
Youngstown, Ohio	Carbon	W. H. McGinnis.
" "	"	"
" "	"	"
" "	"	"
Ohio		"
Ellsworth township, Mahoning Co., O.		" (Crystals in claymatrix).
Island of Redonda, Caribbean Sea.		C. H. Hitchcock—The very best-40 p ct. P_2O_5. For No.'s 7262-7271, see Bul. Geol. Soc. Amer. Vol. II, p. 6.
" "		C. H. Hitchcock.—The compact light colored part is supposed to be nearly pure *Redondite*.
" "		C. H. Hitchcock.—High grade:—Nearly 40 p ct. P_2O_5.
" "		C. H. Hitchcock.—About 35 p ct P_2O_5.

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7266	1891	Exchange	Phosphate rock: representing *redondite*	5
7267	"	"	" " "	5
7268	"	"	" " "	1
7269	"	"	Phosphate earth. "	
7270	"	"	Volcanic tufa	1
7271	"	"	Lava	1
7272	"	"	Calcite	1
7273	"	"	"	1
7274	"	"	"	1
7275	"	"	Trigonocarpon	4
7276	"	"	"	1
7277	May, 1891	Presented	Granitic gneiss	1
7278	1890	"	Iron slag	1
7279	Dec., 1891	Geol. Survey	Philodops trentonensis var minor W. and S.	3 slabs.
7280	July, 1891	"	Subulites elongatus Conrad	7
7281	"	"	Murchisonia tricarinata Hall	2
7282	"	"	Pleurotomaria subconica Hall	8
7284	"	"	Murchisonia helicteres Salter	6
7289	"	"	Raphistoma lenticularis Sowerby	5
7290	"	"	Raphistoma	2
7291	"	"	Maclurea	6
7292	"	"	Cyrtolites compressa Conrad	4
7293	"	"	Bucania (Tremanotus?) buelli Whitfield	2
7294	"	"	Bucania	3
7295	"	"	Bucania bidorsata Hall	1
7296	"	"	Bellerophon	3
7297	"	"	Bellerophon wisconsensis Whitfield	4
7298	"	"	Bellerophon bilobatus Sowerby	25
7303	"	"	Subulites elongatus Conrad	1
7304	"	"	Pleurotomaria subconica Hall	1
7308	"	"	Maclurea bigsbyi Hall	1
7309	"	"	Cyrtolites compressa Conrad	1
7310	"	"	Bellerophon wisconsenis Whitfield	2
7311	"	"	Bellerophon bilobatus Sowerby	6
7312	"	"	Maclurea	1
7313	"	"	Pleurotomaria subconica Hall	3
7314	"	"	Murchisonia tricarinata Hall	3
7316	"	"	Bellerophon wisconsensis Whitfield	1
7317	"	"	Bellerophon bilobatus Sowerby	1
7318	"	"	Bucania (Tremanatus?)	2
7319	"	"	" "	1
7321	"	"	Pleurotomaria subconica Hall	4
7328	"	"	Raphistoma lenticularis Sowerby	4
7330	"	"	Bellerophon bilobatus Sowerby	1
7333	"	"	Raphistoma lenticularis Sowerby	5
7337	Aug. 1891	"	Murchisonia gracilis Hall	19
7343	July 1891	"	Trochonema	1
7344	"	"	Murchisonia gracilis Hall	3
7345	Aug. 1891	"	Murchisonia major Hall	3
7346	"	"	Bellerophon	1
7347	"	"	Trochonema	4
7348	"	"	Raphistoma lenticularis Sowerby	2
7349	"	"	Maclurea	2
7351	"	"	Bellerophon bilobatus Sowerby	12
7352	"	"	Bellerophon wisconsensis Whitfield	1
7353	"	"	Raphistoma lenticularis Sowerby	1
7354	July 1891	"	Bellerophon bilobatus Sowerby	26
7356	"	"	Maclurea	4
7357	"	"	Trochonema	1
7358	"	"	Pleurotomaria subconica Hall	2
7546	"	"	Homotrypa seperata var.	1
7547	"	"	Philloporina reticulata Hall	1
7548	"	"	Rhinidictya fidelis Ulrich	2
7549	"	"	Rhinidictya trentonensis Ulrich	3
7550	"	"	Monotrypa	5
7551	"	"	Leptotrypa hexagonalis Ulrich	1
7552	"	"	Rhinidictya	1
7553	"	"	"	1
7554	"	"	Rhinidictya fidelis Ulrich	1
7555	"	"	Nicholsonella ponderosa	1
7557	"	"	Leptotrypa hexagonalis Ulrich	1

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Island of Redonda, Caribbean Sea		C. H. Hitchcock.—About 27 p ct. P_2O_5.
" "		" About 24 p ct P_2O_5.
" "		" Splendid grains or concretions.
" "		" About 12 p ct P_2O_5.
" "		" From tunnel in midst of workings.
" "		"
New Galilee, Beaver county, Pa		H. W. Williams (Brown).
" "		" (White).
" "		" "
Ohio	Carbon	H. W. Williamson. The Mt. Hope type of the country (nuts in matrix.)
"	"	" (shell of the nut.)
	Taconic?	Frank L. Nason, rock of the N. J. magnetite mines.
Tribune fire, Minneapolis		H. V. Winchell, resembles meteoric iron.
St. Paul, Minn	Trenton	C. Schuchert.
Janesville, Wis	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
Beloit, Wis	"	" from C.&N.W.R.R. qry, 3½m. n. of Beloit.
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
Rockton, Ill	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
Beloit, Wis	"	" fr. Samp's qry. in the "Up. Buff Beds
"	"	"
Neenah, Wis	Galena	"
Oshkosh, Wis	"	"
"	"	"
Graf, Iowa	Cincinnati	"
Janesville, Wis	Trenton	"
"	"	"
Dubuque, Iowa	Galena	"
"	"	"
"	"	"
McGregor, Iowa	Trenton	"
"	"	"
"	"	"
"	"	"
Mineral Point, Wis	"	"
"	"	"
"	"	"
"	"	"
McGregor, Iowa	"	"
"	"	"
Janesville, Wis	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
Near Beloit, Wis	"	"
"	"	"
"	"	"

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7558	July, 1891	Geol. Survey...	Ptilodictya subrecta Ulrich	2
7559	"	"	Batostoma fertile ? Ulrich	1
7560	"	"	Rhinidictya trentonensis Ulrich	1
7561	"	"	Batostomella trentonensis Nicholson	1
7562	"	" ...	Ptilodictya falciformis var. acuminata James	6
7563	"	"	Rhinidictya	1
7564	"	"	Rhinidictya paupera Ulrich	1
7565	"	"	Dekayella	8
7566	"	"	Stellipora antheloidea Hall	1
7567	"	"	? Hemiphragma ottawaense Foord	2
7568	"	"	Homotrypa	111
7569	"	"	Prasopora insularis Ulrich	130
7570	"	"	Prasopora simulatrix Ulrich	33
7571	"	"	Prasopora simulatrix ? Ulrich	1
7573	"	"	Prasopora simulatrix Ulrich	71
7574	"	" ...	Monotrypa nodosa Ulrich (M. S.)	4
7575	"	"	Trematopora ositida Ulrich, et al	1
7576	"	" ...	" " "	1
7577	"	"	Draospora fragilis Billings	2
7578	"	"	Batostomella simulatrix Ulrich	3
7579	"	"	Undetermined ramose forms	Many
7580	"	"	Crepipora hemispherica ? Ulrich	2
7581	"	"	Monotrypella quadrata var. multituberculata Whit.	1
7582	"	"	Heterotrypa	5
7583	"	"	"	1
7584	"	"	Heterotrypa singularis Ulrich	3
7585	"	"	Ceramoporella irregularis Whitfield	8
7586	Aug., 1891	"	Spatiopora	3
7587	"	"	"	4
7589	"	"	Batostomella variabile Ulrich	10
7590	"	"	Crepipora	6
7591	"	"	Prasopora contigua Ulrich	4
7592	"	"	Batostoma minnesotensis ?	2
7593	July, 1891	"	Rhinidictya fidelis Ulrich	1
7594	"	"	" " "	1
7595	"	"	Leptotrypa hexagonalis Ulrich	2
7596	Aug., 1891	"	Pachydictya acuta var. elegans Ulrich	1
7597	"	"	Stictoporella angularis var. intermedia Ulrich	1
7598	"	"	Rhinidictya septata Ulrich	5
7599	"	"	Stictoporella angularis var. intermedia Ulrich	4
7600	"	"	Homotrypa minnesotensis Ulrich	1
7601	"	"	Prasopora insularis Ulrich	141
7602	"	"	Monotrypa cumulata Ulrich	1
7603	"	"	Batostomella trentonensis Ulrich	1
7606	"	"	Batostoma	6
7607	"	"	Pachydictya acuta Hall, et al	1
7608	"	"	" "	1
7609	"	"	" "	1
7611	"	"	Prasopora insularis Ulrich	19
7612	"	"	Rhinidictya paupera Ulrich	1
7613	"	"	Batostoma humile Ulrich	19
7614	"	"	Basal expansion of undet. ramose bryozoans	5
7615	"	"	Callopora pulchera? Ulrich	3
7616	"	"	Pachydictya acuta Hall	5
7617	"	"	Stictoporella angularis Ulrich	2
7618	"	"	Hemiphragma irrasum Ulrich	2
7619	"	"	Pachydictya acuta Hall, et al	13
7620	"	"	Proboscina tumulosa Ulrich	1
7621	"	"	Rhinidictya mutabilis	2
7622	"	"	Prasopora conoidea Ulrich	17
7623	"	"	Pachydictya acuta Hall	1
7624	"	"	Crepipora? denticulata Ulrich	2
7625	"	"	Prasopora occultata Foord	5
7626	"	"	Monotrypa cumulata Ulrich	6
7627	"	"	Hemipragma irrasum Ulrich	1
7628	"	"	Prasopora insularis Ulrich	10
7629	"	"	Monotrypa cumulata Ulrich	1
7631	"	"	Monticulipora ramifera Ulrich	3
7632	"	"	Pachydictya acuta Hall	1
7633	"	"	Dekayia trentonensis Ulrich	2
7635	"	"	Monotrypa cumulata Ulrich	6
7636	"	"	Homotrypa similis Foord	3
7637	"	"	Prasopora insularis Ulrich	8
7638	"	"	Leptotrypa	1

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Near Beloit, Wis.	Trenton	C. Schuchert.
Rockton, Ill.	"	"
"	"	"
Neenah, Wis.	Galena	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
Oshkosh, Wis.	"	"
Iron Ridge, Wis.	Cincinnati	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
Graf, Iowa	"	"
"	"	"
"	"	"
Dubuque, Iowa	Galena	"
McGregor, Iowa	Trenton	"
"	"	"
Mineral Point, Wis.	"	"
"	"	"
"	"	"
Decorah, Iowa	Galena	"
"	Trenton	"
"	Galena	"
"	Trenton	"
"	"	"
"	Galena	"
"	"	"
"	"	"
Six m. s. of Cannon Falls, Minn.	"	Scofield and Schuchert.
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
Preston, Minn.	Trenton	"
Six m. s. Cannon Falls, Minn.	Galena	"
Two m. s. e. "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
Chatfield, Minn.	Trenton	W. H. Scofield.
Holden, Minn.	Galena	"
"	"	"
"	"	"
Seven m. s. Cannon Falls, Minn.	"	Scofield and Schuchert.
" "	"	"
" "	"	"
Kenyon, Minn.	"	W. H. Scofield.
"	"	"
Nine m. s. Cannon Falls, Minn.	"	Scofield and Schuchert.
9 miles south Cannon Falls, Minn.	"	" "
Warsaw, Minn.	"	W. H. Scofield.
" "	"	"

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7639	Aug., 1891.	Geol. Survey...	Pachydictya acuta Hall	5
7640	"	"	Callopora multitabulata Ulrich	6
7641	"	"	Prasopora insularis Ulrich	1
7642	"	"	Monotrypa cumulata Ulrich	1
7643	"	"	Pachydictya acuta? Hall	2
7644	"	"	Prasopora insularis Ulrich	1
7645	"	"	Homotrypa similis Foord	1
7646	"	"	Pachydictya occidentalis? Ulrich	3
7647	"	"	Ceramoporella	1
7649	"	"	Callopora	16
7650	"	"	Stictoporella frondifera Ulrich	2
7652	"	"	Callopora multitabulata Ulrich	5
7653	"	"	Lichenaria typa W and S	1
7654	"	"	Trematopora primigenia Ulrich	1
7655	"	"	Homotrypa exilis Ulrich	1
7656	"	"	Crepipora? denticulata Ulrich	4
7657	"	"	Dekayella	12
7658	"	"	Prasopora	2
7659	"	"	Callopora multitabulata Ulrich	9
7660	"	"	Anolotichia impolita Ulrich	2
7661	"	"	Trematopora primigenia Ulrich	3
7662	"	"	Crepipora? denticulata Ulrich	1
7663	"	"	Rhinidictya mutabilis Ulrich	1
7664	"	"	Batostoma winchelli Ulrich	22
7665	"	"	Callopora multitabulata Ulrich	5
7666	"	"	Prasopora insularis Ulrich	14
7667	"	"	Homotrypa separata Ulrich	1
7668	"	"	Batost ma minnesotensis Ulrich	2
7669	"	"	Dekayella	1
7670	"	"	Homotrypa	8
7671	"	"	Lingula philomela Billings	1
7672	July, 1891.	"	Lingula riciniformis var. galenensis W. and S	3
7673	"	"	" " " " "	10
7674	Aug., 1891.	"	Lingula hurlburti N. H. Winchell	2
7675	"	"	Lingula deflecta W. and S	7
7676	"	"	Lingula deflecta Winchell and Schuchert?	1
7677	July, 1891.	"	Lingula iowensis Owen	11
7678	"	"	" "	5
7679	Aug., 1891.	"	" "	2
7680	"	"	" "	8
7681	"	"	Lingula canadensis Billings	1
7682	"	"	" "	1
7683	July, 1891.	"	Lingulasma galenensis W. and S	1
7684	"	"	" "	1
7685	"	"	" "	3
7686	Aug., 1891	"	" "	1
7687	July, 1891	"	Lingula trentonensis Conrad	3
7688	Aug., 1891	"	Schizotreta pelopea Billings	7
7689	July, 1891	"	" " "	1
7690	"	"	" " "	1
7691	Oct., 1880	" ...	Trematis huronensis Billings	1
7692	July, 1891	"	Crania setigera Hall	4
7693	Aug., 1891	"	" " "	2
7694	July, 1891	"	" " "	3
7695	"	"	" " "	2
7696	"	"	" " "	1
7697	"	"	Crania trentonensis Hall	3
7698	"	"	Lysocrania ulrichi Hall	1
7699	"	"	" " "	2
7700	Aug., 1891	"	" " "	2
7701	"	"	Lysocrania ulrichi ? Hall	1
7702	"	"	Rauffella filosa Ulrich	3
7703	"	"	" " "	17
7704	"	"	" " "	4
7705	"	"	Rauffella ?	1
7706	"	"	Probably the remains of some sponge	2
7707	"	"	Rauffella filosa Ulrich	1
7708	"	"	" " "	1
7709	"	" ...	Cylindrocœlia minnesotensis Ulrich	1
7711	July, 1891	"	Hindia parva Ulrich	19
7712	Sept., 1880	"	Astylospongia	2
7714	July, 1891	" ...	Receptaculites oweni Hall	6
7715	Aug., 1891	"	" " "	10
7716	"	"	" " "	1

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Warsaw, Minn.	Galena	W. H. Scofield.
Mineola, Minn	“	“
“ “	“	“
“ “	“	“
“ “	“	“
4 miles S. W. Cannon Falls, Minn	“	Scofield and Schuchert.
“ “ “	“	“
“ “ “	“	“
“ “ “	“	“
Fountain, Minn	Trenton	“
“ “	“	“
Preston, Minn	“	“
“ “	“	“
“ “	“	“
“ “	“	“
Near Fountain, Minn	“	“
“ “	“	“
“ “	“	“
“ “	“	“
“ “	“	“
“ “	“	“
“ “	“	“
Preston, Minn	“	“
Near Fountain, Minn	“	“
“ “	Galena	“
“ “	“	“
Chatfield, Minn	Trenton	W. H. Scofield.
“ “	“	“
“ “	“	“
“ “	“	“
Granger, Minn	Cincinnati	Mr. R. H. Hasse of Granger.
Neenah, Wis	Galena	C. Schuchert.
Oshkosh, Wis	“	“
Mantorville, Minn	“	W. H. Scofield.
Near Fountain, Minn	“	C. Schuchert.
Spring Valley, Minn	Cincinnati	“
Dubuque, Iowa	Galena	“
Decorah, Iowa	“	“
Near Aspelund, Minn	“	Scofield and Schuchert,
Mantorville, Minn	“	“
“ “	“	C. Schuchert.
Hader, Minn	“	W. H. Scofield.
Neenah, Wis	“	C. Schuchert.
Oshkosh, Wis	“	“
Decorah, Iowa	“	“
Bear creek, S. of Hamilton, Minn	“	“
Janesville, Wis	Trenton	C. Schuchert.
Mantorville, Minn	Galena	Scofield and Schuchert.
Dubuque, Iowa	“	C. Schuchert.
Neenah, Wis	“	“
Minneapolis, Minn	Trenton	C. L. Herrick.
St. Paul, Minn	“	C. Schuchert.
Near Preston, Minn	“	Scofield and Schuchert.
Decorah, Iowa	“	C. Schuchert.
Mineral Point, Wis	“	“
Beloit, Wis	“	C. Schuchert, C. & N. W. R. R. quarries.
Janesville, Wis	“	C. Schuchert.
St. Paul, Minn	“	“
6 miles south of Cannon Falls, Minn.	Galena	Scofield and Schuchert.
Near Fountain, Minn	Trenton	“ “ “
7 miles south of Cannon Falls, Minn.	Galena	“ “ “
Near Fountain, Minn	Trenton	“ “ “
Near Preston, Minn	“	Scofield and Schuchert.
Decorah, Iowa	“	C. Schuchert.
“ “	“	“
2 miles S. E. of Cannon Falls, Minn.	Galena	Scofield and Schuchert.
6 miles south of Cannon Falls, Minn.	“	“ “ “
7 miles south of Cannon Falls, Minn.	“	“ “ “
6 miles south of Cannon Falls, Minn.	“	“ “ “
Oshkosh, Wis	“	C. Schuchert.
Spring Valley, Minn	Niagara	N. H. Winchell.
Dubuque, Iowa	Galena	C. Schuchert.
6 miles south of Cannon Falls, Minn.	“	W. H. Scofield and C. Schuchert.
Sec. 12, Holden, Goodhue Co., Minn.	“	“ “ “

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7717	Aug. 1891	Geol. survey....	Receptaculites oweni Hall................................	2
7718	"	"	Receptaculites oweni ? Hall............................	2
7719	"	"	Receptaculites oweni Hall	2
7720	"	"	" " "	2
7721	"	"	" " "	7
7722	"	"	Receptaculites iowensis Owen..........................	2
7723	"	"	Receptaculites fungosus Hall..........................	1
7724	"	"	Receptaculites globularis Hall........................	3
7725	Sept., 1880.	"	Protarea vetusta Edwards & Haime......................	1
7726	Aug., 1891.	"	Columnaria alveolata Hall.............................	1
7732	"	"	Cretaceous limonite...................................	1
7733	"	Presented.......	Black oxide of manganese..............................	Indef.
7734	July, 1891..	Geol. survey....	Columnaria alveolata Hall.............................	3
7735	Sept., 1891.	"	Limestone concretion from slate (aininike)............	1
7736	"	"	Chert...	1
7737	July, 1891..	"	Streptelasma profundum Hall...........................	13
7738	"	"	" "	20
7739	"	"	" "	2
7740	"	"	" "	156
7741	Aug., 1891.	"	" "	3
7742	"	"	" "	11
7743	"	"	" "	1
7744	July, 1891..	"	Streptelasma corniculum Hall?.........................	12
7745	"	"	" "	6
7746	Aug., 1891..	"	" "	4
7747	"	"	" "	13
7748	"	"	" "	5
7749	"	"	" "	7
7750	"	"	" "	8
7751	"	"	" "	13
7752	"	"	Streptelasma...	2
7753	"	"	Streptelasma rusticum Billings.........................	12
7754	July, 1891..	"	" "	7
7755	Aug., 1891.	"	Diplograptus pristis (Hisinger) Hall..................	4
7756	July, 1891..	"	Diplograptus pristis? (Hisinger) Hall.................	2
7757	"	"	Diplograptus putillus Hall............................	1
7758	"	"	Diplograptus pristis (Hisinger) Hall..................	9
7759	Aug., 1881..	"	Climacograptus typicalis Hall.........................	5
7760	"	"	Diplograptus putillus Hall............................	2
7761	"	"	Dictyonema..	1
7762	July, 1891	"	Orthis (Plectorthis) whitfieldi Winchell..............	10
7763	Aug., 1891	"	" " " "	10
7764	"	"	" " " "	6
7765	"	"	Orthis (Plectorthis) plicatella Hall..................	2
7766	"	"	" " " "	2
7767	July, 1891	"	Orthis (Dinorthis) pectinella Emmons..................	1
7768	Aug., 1891	"	Orthis (Dinorthis) pectinella var. sweeneyi Winchell.	3
7769	July, 1891	"	" " " "	6
7770	Aug., 1891	"	Orthis (Dinorthis) meedsi var. germana W. and S.	3
7771	"	"	Orthis (Dinorthis) meedsi W. and S....................	2
7772	"	"	" " " "	9
7773	"	"	" " " "	10
7774	"	"	" " " "	10
7775	"	"	" " " "	7
7776	"	"	" " " "	4
7777	"	"	" " " "	4
7778	"	"	" " " "	6
7779	"	"	" " " "	6
7780	"	"	" " " "	18
7781	"	"	" " " "	5
7782	"	"	" " " "	5
7783	July, 1891	"	" " " "	4
7784	"	"	" " " "	7
7785	"	"	Orthis (D.) pectinella var. sweeneyi Winchell.........	8
7786	Aug., 1891	"	Orthis (D.) subquadrata Hall	Many
7787	Sept., 1881	Presented	" " "	3
7788	Aug., 1891	Geol. survey....	" " "	4
7789	"	"	Orthis (D.) proavita W. and S.........................	7
7790	July, 1891	"	Orthis (D.) deflecta Conrad...........................	16
7791	"	"	" " "	9
7792	"	"	" " "	6
7793	"	"	Orthis (Dinothis) deflecta Conrad.....................	3
7794	"	"	" "	5
7795	Aug., 1891	"	Orthis tricenaria Conrad..............................	2

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Minneola, Minn	Galena	W. H. Scofield and C. Schuchert.
Stewartsville, Minn	"	" " "
3 miles south of Cannon Falls, Minn.	"	" " "
Near Fountain, Minn	"	" " "
Decorah, Iowa	"	C. Schuchert.
"	"	"
"	"	"
Dubuque, Iowa	"	"
Spring Valley, Minn	Cincinnati	N. H. Winchell.
Preston, Minn	Trenton	C. Schuchert.
Winona county, Minn		
Monticello, Minn		By J. N. Stacy.
Rockton, Ill	Trenton	C. Schuchert.
Beaver Mine, Ont., Can	Animikie	H. V. Winchell.
" "		"
Rockton, Ill	Trenton	C. Schuchert.
Beloit, Wis.	"	" (Samp's quarry.)
Janesville, Wis	"	"
Mineral Point, Wis	"	"
Fountain Minn	"	Scofield and Schuchert.
Preston, Minn	"	"
Cannon Falls, Minn	"	"
Oshkosh, Wis	Galena	C. Schuchart.
Decorah, Iowa	Trenton	"
Nine miles S. of Cannon Falls, Minn.	Galena	Scofield and Schuchert.
Two m. S. E. of Cannon Falls, Minn.	"	"
Kenyon, Minn	"	"
Twelve m. S. of Cannon Falls, Minn.	"	"
Three m. S. of Cannon Falls, Minn	"	"
Seven m. S. of Cannon Falls, Minn	"	"
Florence, Iowa	Cincinnati	"
"	"	"
Graf, Iowa	"	C. Schuchert.
Granger, Minn	"	Scofield and Schuchert.
Graf, Iowa	"	C Schuchert.
"	"	
"	"	
Mantorville, Minn	Galena	Scofield and Schuchert.
Granger, Minn	Cincinnati	"
" "	"	"
Graf, Iowa	"	C. Schuchert.
Spring Valley, Minn	"	Scofield and Schuchert.
Near Granger, Minn	"	"
9 m. S. of Cannon Falls, Minn	Galena	"
12 m. S. of Cannon Falls, Minn	"	"
Decorah, Iowa	Trenton	C. Schuchert.
2 m. S. of Cannon Falls, Minn	"	Scofield and Schuchert.
McGregor, Iowa	"	C. Schuchert.
9 m. S. of Cannon Falls, Minn	Galena	Scofield and Schuchert.
McGregor, Iowa	Trenton	C. Schuchert.
6 m. S. of Cannon Falls, Minn	Galena	Scofield and Schuchert.
12 m. S. of Cannon Fall, Minn	"	"
2 m. S. E. of Cannon Falls, Minn	"	"
3 m. S. W. of Cannon Falls, Minn	"	"
7 m. S. of Cannon Falls, Minn	"	"
Mineola, Minn	"	"
Warsaw, Minn	"	"
Kenyon, Minn	"	"
Fountain, Minn	"	"
Preston, Minn	Trenton	"
Decorah, Iowa	Galena	C. Schuchert.
Neenah, Wis	"	"
Oshkosh, Wis	"	"
Decorah, Iowa	Trenton	"
Spring Valley, Minn	Cincinnati	Scofield and Schuchert.
" "	"	John Kiechler (part of No. 4094)
Graf, Iowa	"	C. Schuchert.
Spring Valley, Minn	"	Scofield and Schuchert.
Janesville, Wis	Trenton	C. Schuchert.
Beloit, Wis	"	"
Mineral Point, Wis	"	"
McGregor, Iowa	"	"
Minneapolis, Minn	"	H. V. Winchell.
2 m. S. of Cannon Falls, Minn	"	Scofield and Schuchert.

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7796	Aug., 1891	Geol. Survey...	Orthis tricenaria Conrad	1
7797	"	"	" "	5
7798	July, 1891	"	" "	35
7799	"	"	" "	5
7800	"	"	" "	3
7801	"	"	" "	14
7802	"	"	" "	10
7803	"	"	" "	3
7804	Aug., 1891	"	" "	7
7805	"	"	" "	5
7806	July, 1891	"	Orthis bellarugosa Conrad	4
7807	"	"	" "	3
7808	"	"	" "	2
7809	"	"	" "	2
7810	"	"	" "	2
7811	Aug., 1891	"	" "	3
7812	"	"	" "	3
7813	July, 1891	"	Orthis insculpta, subquadrata, etc	1
7814	"	"	Orthis insculpta	3
7815	"	"	" "	2
7816	May, 1885	Donation	Platystrophia biforata Schlotheim	1
7817	Aug., 1891	Geol. Survey...	" "	8
7818	"	"	" "	8
7819	"	"	" "	9
7820	"	"	" "	5
7821	"	"	" "	3
7822	"	"	" "	21
7823	"	"	" "	20
7824	July, 1891	"	" "	25
7825	"	"	" "	5
7826	"	"	Platystrophia biforata Schlotheim	5
7827	"	"	" "	5
7828	Aug., 1891	"	" "	2
7829	Nov., 1891	Exchange	Monticulipora mammillata	6
7834	"	"	Orthis lynx	26
7839	"	"	Orthoceras	3
7842	"	"	Murchisonia major	2
7846	"	"	Receptaculites oweni	1
7847	"	"	Halysites catenulatus	1
7848	"	"	" "	1
7849	"	"	Favosites favosus	1
7850	"	"	Zaphrentis	1
7852	"	"	Aulopora cornuta	1
7853	"	"	Strombodes pentagoneus	1
7854	"	"	Favosites forbesi	1
7855	"	"	Stromoptera concentrica	1
7856	"	"	Favosites dumosus	2
7857	"	"	Lithographic limestone	1
7858	"	"	" "	3
7859	"	"	Syringopora harveyi	1
7860	"	"	Spirifera marionensis	3
7361	"	"	Styldlites	2
7862	"	"	Zapdrentis	3
7863	"	"	Zaphrentis elliptica	3
7865	"	"	Productus flemingi	2
7866	"	"	Productus punctatus?	1
7667	"	"	Rhynchonella ringens	2
7568	"	"	Athyris incrassata	2
7869	"	"	Spirifera grimesi	3
7870	"	"	Terebratula rowleyi	1
7871	"	"	Euomphalus latus	2
7890	"	"	Amethystine quartz	1
7891	"	"	Calcareous tufa	1
7892	July, 1891	Geol. Survey...	Orthis (Dalmanella) testudinaria	2
7893	"	"	" " "	5
7894	"	"	" " "	6
7795	Aug., 1891	"	" " "	15
7896	"	"	Orthis (Dalmanella) hamburgensis ? Walcott	5
7897	"	"	Orthis (Dalmanella) testudinaria	3
7898	"	"	" " "	15
7899	"	"	" " "	22
7900	"	"	" " "	12
7901	"	"	" " "	17
7902	April, 1879	"	" " "	30

ADDITIONS.—*Continued.*

GENERAL MUSEUM, 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Near Fountain, Minn	Trenton	Scofield and Schuchert.
Preston, Minn	"	" "
Janesville, Wis	"	C. Schuchert.
Beloit, Wis	"	"
Mineral Point, Wis	"	"
" "	"	"
Decorah, Iowa	"	"
McGregor, Iowa	"	"
12 m. S. of Cannon Falls, Minn	Galena	Scofield and Schuchert.
6 m. S. of " "	"	" "
Rockton, Ill	Trenton	C. Schuchert.
Neenah, Wis	Galena	"
Janesville, Wis	Trenton	"
McGregor, Iowa	"	"
Decorah, Iowa	"	"
Near Fountain, Minn	Galena	Scofield and Schuchert.
Mineola, Minn	"	" "
Iron Ridge, Wis	Cincinnati	C. Schuchert.
" "	"	"
Graf, Iowa	"	"
Cannon Falls, Minn	Galena	Dr. Sandberg.
6 m. S. of Cannon Falls, Minn	"	Scofield and Schuchert.
12 m. S. of " "	"	" "
3 m. S. of " "	"	" "
2 m. S. E. of " "	"	" "
Kenyon, Minn	"	W. H. Scofield.
Near Fountain, Minn	"	Scofield and Schuchert.
Decorah, Iowa	"	C. Schuchert.
Oshkosh, Wis	"	"
Neenah Wis	"	"
Iron Ridge, Wis	Cincinnati	"
Graf, Iowa	"	"
Preston, Minn	Trenton	Scofield and Schuchert.
Louisville, Kentucky	Hudson River	From Rev. Wm. H. Barris.
Shelby county, Kentucky	Silurian	"
" "	"	"
Pike county, Mo	Trenton	"
Ralls county, Mo	"	"
Jones county, Iowa	......	"
" "	Silurian	"
" "	Niagara	"
" "	"	"
" "	Hamilton	"
" "	Niagara	"
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" "	"	"
Fort Erie, Canada	Hamilton	"
Pike county, Mo	Choteau	"
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Marion county, Mo	"	"
"	Burlington	"
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Anderson county, S. C	......	"
Marion county, Mo	......	"
Rockton, Ill	Trenton	C. Schuchert.
Mineral Point, Wis	"	"
McGregor, Iowa	"	"
Decorah, Iowa	"	"
Preston, Minn	"	Scofield and Schuchert.
Fountain, Minn	"	" "
" "	Galena	" "
2 miles S. E Cannon Falls	"	" "
4 miles south of Cannon Falls, Minn.	"	" "
Mineola, Minn	"	W. H. Scofield.
Kenyon, Minn	"	N. H. Winchell.

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7903	July, 1891	Geol. Survey...	Orthis (Dalmanella) testudinaria	55
7904	"	"	" " "	3
7905	"	"	" " "	22
7906	Aug., 1891	"	" " "	14
7907	"	"	" " "	1 slab.
7908	"	"	" " "	4
7909	"	"	" " "	9
7940	"	Exchange	Jacupirangite, pyroxene facies	1
7941	"	"	Jacupirangite, nepheline facies....................	1
7942	"	"	Jacupirangite..............................	1
7943	"	"	Jacupirangite, magnetite facies..................	1
7944	"	"	Magnetite bearing rock.......................	1
7945	"	"	" " "	1
7946	"	"	" " "	1
7958	"	Geol. Survey...	Crania setigera Hall	1
7959	July, 1891	"	Orthis (Dalmanella)subæquata Conrad..............	5
7960	"	"	" " " "	13
7961	"	"	" " " "	Indef.
7962	"	"	" " " "	7 slabs
7963	Aug., 1891	"	" " " "	18
7664	"	" ...	" " " "	16
7965	"	"	" " " "	9
7966	"	"	" " " "	4
7967	"	"	" " " "	12
7968	"	"	" " " "	10
7969	July, 1891	"	Orthis (D.) subæquata var. gibbosa Billings..........	1
7970	Aug., 1891	" ...	" " " "	Inde
7971	"	"	" " " "	1
7972	"	"	" " " "	3
7973	July, 1891	"	Orthis (D.) subæquata var. perveta Conrad	5
7974	"	"	" " " "	1
7975	"	"	" " " "	3
7976	"	"	" " " "	3
7977	....	"	" " " "	7
7978	1876-1879	"	Orthis (D.) subæquata var. conradi Winchell..........	1
7979	"	"	" " " "	5
7980	July, 1891	"	" " " "	4
7981	"	"	" " " "	3
7982	"	"	" " " "	1
7983	Aug., 1891	"	Lingula riciniformis var. galenensis W. and S..........	1
7984	July, 1891	"	Stictoporella angularis var intermedia Ulrich.......	2
7985	Aug., 1891	"	Orthis testudinaria var. meeki.	Indef.
7986	July, 1891	"	Streptelasma profundum Hall	27
7987	"	"	Fenestella granulosa Whitfield...	Slab.
7988	"	"	Fistulipora (??) solidissima Whitfield..................	14
7989	"	"	Batostomella...................................	6
7690	"	"	Constellaria insincera Ulrich (MS.).................	3
7991	"	"	Batostomella simulatrix Ulrich.....................	4
7992	"	"	Trematopora annulifera Whitfield..................	1
7993	"	"	Batostomella.....................................	13
7996	"	"	Homotrypa......................................	6
7997	"	"	? Fistulipora lens Whitfield..........................	3
7998	"	"	Monotrypella quadrata var. rectangularis Whitfield	16
7999	"	"	Batostoma.......................................	10
8000	"	"	"	4
8001	"	"	Atactoporella....................................	3
8002	"	"	Callopora.......................................	2
8003	"	"	Callopora rugosa Whitfield.........................	12
8004	"	" ...	Homotrypella....................................	6
8005	"	"	Atactoporella....................................	8
8008	"	"	Constellaria polystomella Nich......................	1
8009	"	"	Ceramoporella granulosa Ulrich.	11
8010	"	"	Ceramoporella minima Ulrich (MS)..................	5
8011	"	"	Crepipora simulans Ulrich..........................	1
8012	"	"	Anolotichia ponderosa Ulrich	1
8013	"	"	Stromotopora arachnoidea Hall......................	2
8014	"	"	Batostoma.....	2
8015	"	"	Batostomella gracilis Nicholson......................	1
8016	"	"	Batostomella simulatrix Ulrich.......................	4
8017	"	"	Monotrypella multituberculata Whitf................	2
8018	"	"	Monotrypella rectangularis Whitf..................	5
8019	"	"	Callopora crenulata Ulrich..........................	1
8020	"	"	Callopora multitabulata Ulrich......................	17
8021	"	"	Homotrypa similis Foord............................	4

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Granger, Minn	Galena	Scofield and Schuchert.
Dubuque, Iowa	"	C. Schuchert.
Oshkosh, Wis	"	"
Neenah, Wis	"	"
Decorah, Iowa	"	"
Graf, Iowa	Cincinnati	"
Iron Ridge, Wis	"	"
Jacupiranga, Brazil		O. A. Derby.
" "		"
" "		"
" "		" alteration to mica and then to secondary silica.
Ipanema, Brazil		" alteration to secondary silica.
" "		" alteration, with barite, tridymite, etc
" "		" alteration, with secondary silica.
Chatfield, Minn	Trenton	W. H. Scofield.
Mineral Point, Wis	"	C. Schuchert.
McGregor, Iowa	"	"
Decorah, Iowa	"	"
" "	"	"
Preston, Minn	"	Scofield and Schuchert.
Fountain, Minn	"	" "
Chatfield, Minn	"	W. H. Scofield.
2 m. S. E. of Cannon Falls, Minn	"	Scofield and Schuchert.
Minneapolis, Minn	"	C. L. Herrick.
St. Paul, Minn	"	C. Schuchert.
Mineral Point, Wis	"	"
Chatfield, Minn	"	Scofield and Schuchert.
Decorah, Iowa	"	C. Schuchert.
Minneapolis, Minn	"	C. L. Herrick.
Janesville, Wis	"	C. Schuchert.
Beloit, Wis	"	"
Mineral Point, Wis	"	"
Decorah, Iowa	"	"
Near Fountain, Minn	"	N. H. Winchell.
Minneapolis, Minn	"	C. L. Herrick (From No. 5088.)
" "	"	"
Janesville, Wis	"	C. Schuchert.
Beloit, Wis	"	"
Decorah, Iowa	"	"
Fountain, Minn	Galena	Scofield and Schuchert.
Preston, Minn	Trenton	" "
Spring Valley, Minn	Hudson River	" "
Decorah, Iowa	Trenton	C. Schuchert.
Iron Ridge, Wis	Hudson River	"
Near Iron Ridge, Wis	"	"
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Graf, Iowa	"	"
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6 m. S. Cannon Falls, Minn	Galena	Scofield and Schuchert.
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MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specim
8022	July, 1891	Geol. Survey...	Dekayia trentonensis Ulrich	1
8023	"	" ..	Petigopora asperula Ulrich	1
8024	"	"	Prasopora contigua Ulrich	11
8025	"	"	Monotrypa cumulata Ulrich	1
8026	Aug., 1891	"	Basal portion of Batostoma species	1
8027	"	"	Pachydictya acuta Hall	1
8028	"	"	Phylloporina reticulata Hall	1
8029	"	"	Dekayia trentonensis Ulrich	2
8030	"	"	Homotrypa subramosa	10
8031	"	"	Ceramoporella	2
8032	"	"	Hemiphragma peculiare Ulrich	1
8033	"	"	Hemiphragma irrasum Ulrich	2
8034	"	"	Batostomella trentonensis Nicholson	13
8035	"	"	Monticulipora ramifera Ulrich	4
8037	"	"	Prasopora conoidea Ulrich	2
8038	"	"	Callopora crenulata Ulrich	1
8039	"	"	Calopora multitabulata Ulrich	27
8040	"	" ...	Batostomella trentonensis Nicholson	6
8041	"	"	Hemiphragma irrasum Ulrich	5
8042	"	"	Hemiphragma peculiare Ulrich	2
8043	"	"	Homotrypa similis Foord	1
8044	"	"	Constellaria incipiens Ulrich	1
8045	"	"	Stomatopora inflata Hall	1
8046	"	"	Prasopora insularis Ulrich	6
8047	"	"	Probiscina tumulosa Ulrich	1
8048	"	"	Monticulipora ramifera Ulrich	3
8049	"	"	Callopora multitabulata Ulrich	25
8050	"	"	Batostomella trentonensis Nicholson	12
8051	"	"	Hemiphragma irrasum Ulrich	4
8052	"	"	Hemiphragma peculiare Ulrich	5
8053	"	"	Ceramoporella	1
8055	"	"	Solenopora compacta Billings	1
8056	"	"	Batostoma	3
8057	"	"	Prasopora insularis Ulrich	2
8058	"	"	Homotrypa similis Foord	9
8059	July, 1891	"	Diploporella obliquata Ulrich (MS.)	1
8060	"	" ...	Leptotrypa acervulosa Ulrich	14
8061	"	"	Homotrypa subramosa Ulrich	4
8062	"	"	Monticulipora ramifera Ulrich	4
8063	"	"	Batastoma humile Ulrich	4
8064	"	" .	Hemiphragma irrasum Ulrich	3
8065	"	"	Petigopora	1
8066	"	"	Stomatopora proutana Miller	1
8067	"	"	Callopora multitabulata Ulrich	11
8068	"	"	Callopora crenulata? Ulrich	2
8069	"	"	Nematopora ovalis Ulrich	1
8070	"	"	Homotrypa minnesotensis Ulrich	14
8071	"	"	Homotrypa	1
8072	"	" ...	Batostoma fertile? Ulrich	2
8073	"	"	Dekayella	1
8074	"	"	Nicholsonella	1
8075	"	"	Arthropora simplex Ulrich	1
8076	"	"	Rhinidictya nicholsoni Ulrich	1
8077	"	"	Batostoma	15
8078	"	"	Hemiphragma irrasum Ulrich	3
8079	"	"	Batostomella trentonensis Ulrich	6
8080	"	"	Homotrypella	5
8081	"	"	Batostomella nana Ulrich	1
8082	"	"	? Callopora crenulata Ulrich	3
8083	"	"	Callopora multitabulata Ulrich	6
8084	"	"	Batostomella	6
8086	"	"	Monticulipora	10
8087	Aug., 1891	"	Batostoma?	6
8088	"	"	Callopora angularis Ulrich	3
8089	"	"	Atactopora typicalis var. praecursor Ulrich	1
8090	"	"	Homotrypa minnesotensis Ulrich	2
8091	"	"	Homotrypa exilis Ulrich	1
8092	"	"	Batostoma winchelli Ulrich	5
8093	"	"	Batostoma minnesotensis?	1
8094	"	"	Atactoporella typicalis var. praecursor Ulrich	1
8095	"	"	Batostoma winchelli var. Ulrich	2
8096	"	"	Callopora multitabulata Ulrich	7
9097	"	"	Callopora angularis Ulrich	1
8098	"	"	Dekayella	6
8099	"	"	Homotrypa subramosa Ulrich	2
8100	"	"	Bythopora herricki Ulrich	2

ADDITIONS—*Continued.*

GENERAL MUSEUM, 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
6 m. S. of Cannon Falls, Minn	Galena	Scofield and Schuchert.
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Preston, Minn	Trenton	" "
6 m. S. of Cannon Falls, Minn	"	" "
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7 m. S. of Cannon Falls, Minn	"	" "
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2 m. S. of Cannon Falls, Minn	"	" "
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" " "	Galena	" "
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Kenyon, Minn	"	W. H. Scofield.
Holden, Minn	"	"
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Decorah, Iowa	"	C. Schuchort.
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Neenah, Wis	"	"
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Chatfield, Minn	Trenton	W. H. Scofield.
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Near Fountain, Minn	"	Scofield and Schuchert.
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VI.

ADDITIONS TO THE LIBRARY SINCE THE REPORT OF 1889.

A

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E

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J

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P

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R

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S

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VII.

CATALOGUE OF THE METEORITES IN THE UNIVERSITY COLLECTION, WITH REFERENCES TO LITERATURE DESCRIBING THEM.

A number is given to each fall represented in the collection. Where there are several specimens from the same fall small italicized letters are used. A complete bibliography of the following meteorites has not been attempted, but under each fall we have tried to give the reference to the first description, and to other articles containing exhaustive descriptions, or new facts not mentioned in the first description. The catalogue is arranged chronologically as to the dates of fall or discovery.

No. 1. **Medvedewa, Krasnojarsk, Siberia. [The Pallas Iron.]** Found in 1749. Museum number, 4119.

G. Rose; Pogg. Ann., 1825, iv, p. 186.

N. von Kokscharow; Bull. l'Acad. Imp. Soc. St.-Pétersbourg, 1870, xx, No. 3.—Mémoires l'Acad. Imp. Soc. St.-Pétersbourg, xv, No. 6.—Jahrb. Mineralogie, 1870, p. 778.

A. Langier; Mem. Mus. Hist. Nat., 1817, iii, pp. 341-352.

E. H. von Baumhauer; Archives Néerlandaises, 1871, vi.

G. von Helmersen; Zeitsch. Deutsch. Geol. Gesell., xxv, p. 347. A Goebel; Bull. Ac. Imp. Sc., St.-Pétersbourg, 1874, xx, p. 100.

Iron. Irregular ragged specimen of a coarse metallic sponge, enclosing olivine in more or less rounded cavities. Most of the olivine has fallen out. Weight, 144 grams.

[*By exchange with Yale College.*]

No. 2. **Istlahuaca, Toluca, Mexico.** Found in 1784. Museum number, 4694.

Gazeta de Mexico, 1784-'85, vol. i, pp. 146, 200.

W. J. Taylor, Proceed. Acad. Nat. Sci. Phila., 1856, vol. viii, pp. 128-130.—Am. Jour. Sci., 1856, [2], xxii, pp. 374-376.

Iron. Irregular rusted piece. Two sides polished, one of them showing well marked Widmannstättian figures. Weight, 105.6 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 3. **Zacatecas, Mexico.** Found in 1792. Museum number, 4696.

C. Bergmann; Neues Jahrb. Min., 1856, p. 297.

H. Mueller; Quart. Jour. Chem. Soc., 1859, xi, pp. 236–240.

a. Iron. Irregular fragment. One side polished, the others rusted. Weight, 1.45 grams.

b. Smaller rusted fragments similar to *a*. Weight, 2.18 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 4. **Albacher Muehle, Bitburg, Rhenish Prussia.** Found in 1802. Museum number, 4416.

J. F. John; Jour. Chemie u. Physik, 1826, xlvi, p. 386.

Iron. Small fragment, much rusted and similar in appearance to the Ovifak iron. Weight, 4.55 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 5. **Durango, Mexico.** Found in 1804(?). Museum number, 4419.

Iron. Fragment which has been hammered and one end broken off. Weight, 10 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 6. **Weston, Fairfield Co., Connecticut.** Fell at 6:30 a. m., Dec. 14, 1807. Museum number, 4122.

Profs. Silliman and Kingsley; Am. Jour. Sci., 1869 [2], xlvii, pp. 1–8.

(This account is reproduced from the Memoirs of the Connecticut Academy of Arts and Sciences)

Stone. Gray ground-mass holding chondri and grains of iron scattered through it. Fragment with a small portion of the crust attached. Weight, 5 grams.

[*By exchange with Yale College.*]

No. 7. **Stannern, Iglau, Moravia.** Fell at 6 a. m., May 22, 1808. Museum number, 4408.

J. Moser; Ann. Physik, 1808, xxix, pp. 309–327.

C. Rammelsberg; Ann. Physik, 1851, lxxxiii, pp. 591–597.

G. Tschermak; Min. Mittheil., 1872, heft ii, p. 83.

a. Stone. Light gray fragment. One face has a black vitreous crust. Weight, 0.95 grams.

b. Smaller fragment of the same. One side shows crust. Weight, 0.4 gram.

c. Smaller fragments. Weight, 0.13 gram.

[*By exchange with Prof. C. U. Shepard.*]

No. 8. **Babb's Mill, Green Co., Tennessee.** Found in 1818. Museum number, 3351.

G. Troost; Am. Jour. Sci., 1845, [1], xlix, pp. 342–344.
C. U. Shepard; Am. Jour. Sci., 1847, [2], iv, pp. 76–77.
W. S. Clark; Metallic meteorites, 1852, pp. 65–66.

Iron. Thin slab; one side has been polished and etched but shows no distinct figures. Two of the edges show crust. Weight, 21 grams. "Its color is rather whiter than that of pure iron; and it is very malleable, equal, if not superior, in this respect to the softest wrought iron." (Am. Jour. Sci., [1], xlix, p. 343.)

[*By exchange with Prof. J. L. Smith.*]

No. 9. **Juvenas, Ardeche, France.** Fell at 3:30 p. m., June 15, 1821. Museum number, 3339.

L. N. Vauquelin; Ann. Chemie u. Physik, 1821, xviii, pp. 421–423.
A. Langier; Ann. Chemie u. Physik, 1821, xix, pp. 264–273.
C. Rammelsberg; Ann. Physik. Chemie, 1838, lxxviii, pp. 585–500.

a. Stone. Fine grained, gray, crumbling, showing almost no iron. Weight, 0.98 grams.

b. Two smaller fragments of the same, showing part of a black vitreous crust. Weight, 0.42 grams.

c. Four smaller fragments. No crust. Weight, 0.42 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 10. **Coahuila, Mexico.** Museum numbers, 3349 and 3361. Found in 1827 (?). Museum numbers, 3349 (*b*), 3361 (*a*).

J. L. Smith; Amer. Jour. Sci., 1855, [2], xix, pp. 160–161; 1869, [2], xlvii, pp. 383–385; 1876, [3], xii, pp. 109–110; 1878, [3], xvi, pp. 270–272.

a. Iron. Rectangular block, with five faces polished, the sixth face showing a dull brown rusted surface. Weight, 3060 grams.

b. Daubréelite from the above meteorite. Weight, 0.0562 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 11. **Drake Creek, near Nashville, Tennessee.** Fell at 4 p. m., May 9, 1827. Museum number, 3353.

H. Seybert; Am. Jour. Sci., 1830, [1], xvii, pp. 326–328.
E. H. Baumhauer; Ann. Physik. Chemie, 1845, lxvi, pp. 498–503.

a. Stone. Gray, fine-grained groundmass, with many small grains of iron. One face has a dull brown crust Weight, 13.5 grams.

b. A smaller fragment of the same. Weight, 2 grams.

[*Ry exchange with Pro J. L. Smith.*]

No. 12. **Vouille, Poitiers, Vienne. France.** Fell July 18, 1831. Museum number, 4697.

Stone. Gray, sprinkled with bright iron grains. No crust. Weight, 0.4 gram.

[*By exchange with Prof. C. U. Shepard.*]

No. 13. **Coahuila, Mexico. [Butcher Irons.** Found in 1837. Museum number, 3358.

J. L. Smith; Am. Jour. Sci., 1855, [2], xix, pp. 160–161; 1867, [2], xliii, pp. 384–385; 1869, [2], xlvii, pp. 383–385.

Iron. Cut slab, not polished ; one side shows a grain o daubréelite surrounded by troilite. Weight, 67.35 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 14. **Cold Bokkeveld, Cape of Good Hope, Africa**. Fell at 9 a. m., Oct. 13, 1838, Museum number, 3341.

M. Faraday; Philosoph. Trans., 1839, pp. 83–87.

E. P. Harris; Sitz. Wien Akad., 1859, xxxv, pp. 5–12.

Stone. Black, with white specks, but apparently no iron. Weight, 1.45 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 15. **Pine Bluff, Little Piney, Missouri.** Fell at 3:30 p. m., Feb. 13, 1839. Museum number, 4,410.

C. U. Shepard; Am. Jour. Sci., 1840, [1], xxxix, pp 254–255.

Stone. Light gray, with darker grains and small specks of iron scattered through it. Fragment, without crust. Weight, 1.4 grams.

[*By exchange with Prof. C. U. Shepard*]

No. 16. **Putnam County, Georgia.** Found in 1839. Museum number, 4693.

J. E. Willet; Am. Jour. Sci., 1854, [2], xvii, pp. 331-332.

Iron. Small irregular fragment, much rusted. Weight, 34 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 17. **Coney Fork, Carthage, Smith County, Tennessee.** Found in 1840. Museum number, 3348.

E. Boricky; Neues Jahrb. Min., 1866, pp. 808-810.

Iron. Specimen with three cut faces at right angles, to each other. These faces are polished and two of them show Widmannstättian figures. Weight, 193.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 18. **Magura, Szlanicza, Arva, Hungary.** Found in 1840. Museum number, 4123.

A. Loewe; Neues Jahrb. Min., 1849, p. 199.

C. Bergmann; Ann. Physik. Chemie, 1857, pp. 256-260.

A. W. Wright; Am. Jour. Sci., 1875, [3], ix, pp. 294-302.

Iron. Irregular specimen with one face polished, another showing the crust. Largely made up of bright nickeliferous iron. Weight, 23 grams.

[*By exchange with Yale College.*]

No. 19. **Pusinsko Selo, Milena, Croatia.** Fell at 3 p. m., April 26, 1842. Museum number, 4411.

Stone. Light gray fragment with no crust. Shows grains of iron. Weight, 2.51 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 20. **Bishopville, South Carolina.** Fell March 25, 1843. Museum number, 4699.

C. U. Shepard; Am. Jour. Sci., 1846, [2], ii, pp. 379-381; 1848, [2], vi, pp. 411-414.

W. S. von Walterhausen; Ann. Chem. Pharm., 1851, lxxix, pp. 369–374.

J. L. Smith; Am. Jour. Sci., 1855, [2], xix, pp. 162–163; 1864, [2], xxxviii, pp. 225–226.

G. Rose; Abh. Berlin. Akad., 1863, pp. 117–122.

C. Rammelsberg; Abh. Berlin. Akad., 1870, pp. 121–123.

M. E. Wadsworth; Am. Jour. Sci., 1883, [3], xxvi, pp. 32–36, 248.—Mem. Mus. Comp. Zool., 1884, xi, pt. 1, pp. 199–201.

G. Tschermak; Die Mikros. Besch. der Meteoriten. 1883, i, pp. 9, 10.—Sitz. Wien. Akad., 1883, lxxxviii, [1], pp. 363–365.

Stone. White and gray. A number of small fragments and some powder; also a few fragments of the crust.

In 1846, Shepard described three new minerals from this meteorite, —chladnite, idiolite and apatoid. The last two are usually considered as easily decomposable compounds of sulphur with other elements of the stone. The silicate, chladnite, has aroused much discussion, and several mineralogists have investigated the meteorite because of this mineral. The general opinion seems to be

that chladnite is similar to enstatite. But Wadsworth says; "Chladnite ought no longer to be regarded as enstatite of the purest kind, as stated in most mineralogies, but rather as a mineral aggregate of which enstatite, feldspar and augite are the principal constituents.

Weight 2.49 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 21. **Sevier County, Tennessee.** Found in 1845. Museum number, 3346.

Iron. Irregular rusted fragment of nickeliferous iron. This meteorite is supposed to be identical with the one which was described in 1840 from Crosby's Creek, Cocke Co., Tennessee. Other specimens contain nodules of graphite. Weight 46.5 grams.

[*By exchange wit i J. L. Smith.*]

No. 22. **Hartford, Linn Co., Iowa.** Fell at 2:45 p. m., Feb. 25, 1847. Museum number, 3761.

C. U. Shepard; Am. Jour. Sci., 1847, [2], iv, pp. 288–289; 1848, [2], vi, pp. 403–405.

C. Rammelsberg; Monatsber. Ak. Wiss. Berlin, 1870, lxx, pp. 457–459.

Stone. With light gray groundmass showing chondritic structure, and with numerous grains of iron, some of them quite large. One face polished. Two of the edges show a dull black earthy crust.

Shepard remarks; "The most remarkable feature of the Iowa stone, however, consists in the homogeneousness of its earthy composition. It appears to contain but a single mineral species of this description, and this one which, though perhaps the most common in other meteoric stones, has until now escaped a separate recognition. I have therefore ventured to bestow upon it a distinct name, that of *howardite*." Rammelsberg later found that howardite was mainly a mixture of olivine and bronzite.

Weight 21 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 23. **Murfreesboro, Rutherford Co., Tennessee.** Found in 1847. Museum number, 3355.

G. Troost; Am. Jour. Sci., 1848, [2]. v. pp. 351–352.

Iron. Slab with one face polished and etched. Shows typical Widmannstättian figures. Weight 66.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 24. **Monroe, Cabarras Co., North Carolina.** Fell at 3 p. m., Oct. 31, 1849. Museum number, 4698.

J. H. Gibbon; Am. Jour. Sci., 1850, [2], ix, pp. 143–146.

C. U. Shepard; Proc. Am. Assoc. Adv. Sci., 1850, iii, pp. 149–152.

Stone. Small fragment without any crust. Dark gray with light grains, and thickly sprinkled with iron. Weight 3.1 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 25. **Union County, Georgia.** Found in 1853. Museum number, 4414.

Iron. Small fragments, much rusted. Weight, 0.63 gram. [*By exchange with Prof. C. U. Shepard.*]

No. 26. **Sarepta, Saratov, Russia.** Found in 1854. Museum number, 4413.

J. Auerbach; Sitz. Wien Akad., 1864, xlix, [2], p. 497.

Iron. Cuttings. Weight, 2.5 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 27. **Cranbourne, near Melbourne, Victoria, S. Australia.** Found in 1854. Museum number, 3341.

W. Haidinger; Sitz. Akad. Wiss., xliv, April 18, June 6, and Oct. 17, 1861; xlv, Jan. 9, 1862.

Walter Flight; Phil. Trans., 1882.—Chapter in the history of meteorites, 1887, pp. 174-181.

a. Iron. Rough fragment, almost silver-gray in color. Weight, 3.9 grams.

b. Another similar fragment. Weight, 3.5 grams.

c. Fifteen smaller pieces. Weight, 4.08 grams.

"This meteorite contains many nodules of troilite lying here and there amongst the plates and crystals of nickel-iron, always in rounded masses, only very occasionally an ill-defined cleavage plane being met with. They vary in size from half an inch to more than two inches in length, are usually covered with a thin layer of graphite, sometimes with some daubreelite surrounding them; and one nodule, consisting of graphite, was found to inclose troilite, which had aggregated inside the graphite in a curious way, so that the section of the nodule suggested the outline of a holly-leaf. * * * * Graphite occurs occasionally, but rarely, as nodules; sometimes as nodules inclosing troilite, like the one already referred to; sometimes in large sheet-like masses, in one case about four inches in length and two inches wide. (*Walter Flight.*)

[*By exchange with Prof. J. L. Smith.*]

No. 28. **Pernallee, Madura District, Madras, India.** Fell at noon, Feb. 28, 1857. Museum number, 4124.

E. Pfeiffer; Sitz. Wien Akad., 1863, xlvii, [2], pp. 460-463.

S. Meunier; Compt. rend., 1871, lxxiii, p. 346.

Stone. Dark gray, with large white, dark-gray and brown grains. Dull black crust and polished face, showing specks of iron distributed through the mass.

"Its structure has been described as pisolitic: Meunier, on the contrary, likens it to a coarsely granular grit. The grains composing it are often angular, sometimes more or less rounded, and in each instance have the characters of fragments which have been detached from larger masses: the rock, in short, is a breccia. During a careful examination of its four specimens preserved in the Paris collection, Meunier noted the presence of twelve distinct species of grains. * * * * * The presence, says the author, in the 'polygenic conglomerate' of Parnallee of fragments belonging to seven types at least of distinct meteoric rocks, demonstrates the co-existence of these types in the star-mass whence this Indian meteorite came." (Walter Flight.) Weight, 8 grams.

[*By exchange with Yale College.*]

No. 29. **Trenton, Washington County, Wisconsin.** Found in 1858. Museum number, 3360.

J. L. Smith; Am. Jour. Sci., 1869, [2], xlvii, pp. 271-272.

Fr. Brenndecke; Ann. Rep. Smithsonian Inst. for 1869, 1871, pp. 417-419.

J. A. Lapham; Am. Jour. Sci., 1872, [3], iii, p. 69.

Iron. Slab with one of the edges showing crust. One face has been polished and etched and now shows very well marked Widmannstättian figures; it also shows what Prof. Smith called "Laphamite markings." These he figured, and described as follows:

"A polished surface when etched gives well marked Widmannstättian figures. There is something, however, peculiar about the markings on this iron, which is doubtless common to other irons, but which has heretofore escaped my observation, and I cannot discover, in a hasty investigation, that it has been noticed by others. My attention was called to this peculiarity by Mr. Lapham, on a slice of the meteorite sent him etched; should these markings be entitled to a separate notice, I propose calling them *Laphamite markings.* The little drawing accompanying this, which is on a somewhat exaggerated scale, will show what they are. The Widmannstättian figures are *a*, bright metallic, with convex ends and sides; *b c*, of a darker color, are the other markings, usually smaller and with the sides and ends concave. The material of which these dark figures are composed, seems to have enveloped the lighter colored portion, which serves to make the dark lines so beautifully conspicuous. A good pocket glass will show that the darker figures are striated, with lines at nearly right angles to the bounding surfaces. When the figure is nearly square, the lines extend from each of the four sides, but when much enlongated, as at *c*,

they are parallel with the longer sides. Often these lines do not reach the middle of the figure, where only a confused crystallization can be detected. In the interior of the enlongated figures, the lines are quite irregular, often running together, and showing a striking resemblance to woody fibre. The nature of these markings may be readily understood. They indicate the axes of minute columnar crystals, which tend to assume a position at right angles to the surface of cooling." The specimens in the museum shows markings that answer well to the above description and to the figure mentioned.

Weight, 180 Grams.

[*By exchange with Prof. J. L. Smith.*]

No. 30. **Staunton, Augusta County, Virginia.** Found in 1858. Museum number 4120.

J. W. Mallet; Am. Jour. Sci., 1871, [3], ii, pp. 10-15; 1878, [3], xv, pp. 337-338.—Brit. Assoc. Report (Brighton), 1872, p. 77.—Proc. Royal Soc., xx, p. 365.—Pogg. Ann., cxlvii, p. 134.

Iron. Slab, with one face etched, showing well marked Widmannstättian figures. Edges with crust. Mallet made four analyses of different pieces of this meteorite and each time found a very small percentage of tin. Weight 90 grams.

[*By exchange with Yale College.*]

No. 31. **Coopertown, Robertson County, Tennessee.** Known in 1860. Museum number 3356.

J. L. Smith; Am. Jour. Sci., 1861, [2], xxxi, p 266.

Iron. Slab with both faces polished; one showing very large Widmannstättian figures distinctly, the other in distinctly. Weight 94 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 32. **Orgueil, Tarn-et-Garonne, France.** Fell at 8 p. m., May 14, 1864. Museum number 3340.

S. Cloez; Comptes Rendus, 1864, lix, pp. 37-40.

F. Pisini; Comptes Rendus, 1864, lix, pp. 132-135.

Stone. No iron. Dead black with white specks and dull black crust. Weight, 1.683 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 33. **Bonanza, Coahuila, Mexico.** Found in 1865. Museum number, 3758.

C. U. Shepard; Am. Jour Sci., 1867, [2], xliii, pp. 384-385.

Iron. Irregular fragment, three of whose faces are polished. Two of these have been partially etched and show Widmannstättian figures rather indistinctly. Weight, 39.8 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 34. **Knyahinya Unghvar, Hungary.** Fell at 5 p. m., June 9, 1866. Museum numbers, 3350(*a*) and 3760(*b*).

A. Kenngott; Sitzber. Ak. Wiss. Wien, 1869, lix, p. 873. —Phil. Mag., 1869, xxxvii, p. 424.

J. V. Schiaparelli; Entwurf einer astronomischen Theorie der Sternschnuppen, 1871, Stettin: Nahmer., p. 267.

E. H. von Baumhauer; Archives Néerlandaises, 1872, vii, p. 146.

W. von Haidinger; Sitzber. Ak. Wiss. Wien, liv. 200 and 513.

G. Rose; Monatsber. Ak. Wiss. Berlin, lxvii, p. 203.

a. Stone. One face polished showing light and dark colored chondri and specks of iron. Three of the faces are covered with a dark crust. A fifth shows a broken surface with the iron rusted.

"It is computed that over a limited area more than a thousand stones, weighing in all from 8 to 10 cwt., must have fallen. The largest found is now preserved in the Vienna collection; it weighs 293.3 kilog. (5 cwt. 3 qrs. 3 lbs.), and measures 2 ft. 4 in. long and 18 in. broad, and penetrated the ground to a depth of 11 feet. * * * * * To the naked eye the section appears to be finely granular and of a gray tint, and even with a very moderate power is seen to present spherular structure, recalling, if relative size be left out of consideration, that of the globular diorite of Corsica. The opaque ingredients are nickel-iron, troilite and a black substance; in addition to these are two crystalline mineral species, the one colorless and transparent and somewhat fissured, the other gray and translucent and presenting an appearance of lamellar structure; both appear in angular and rounded granules, and both are bi-refractive; they are differently affected by hydrochloric acid, and from other differences in their crystalline characters it may be inferred that the gray silicate is an enstatite, the colorless silicate is olivine.*

Weight, 14 grams.

[*By exchange with Prof. J. L. Smith.*]

b. Stone. Bluish gray, with grains of iron sprinkled through it, in some places in groups. Weight, 5.82 grams.

[*By exchange with Prof. C. U. Shepard.*]

*Walter Flight; a Chapter in the History of Meteorites, p. 145.

No. 35. **Bear Creek, Denver Co., Colorado.** Found in 1866. Museum number, 4691.

C. U. Shepard; Am. Jour. Sci., 1866, [2], xlii, pp. 250–251.

J. Henry; Am. Jour. Sci., 1866, [2], xlii, pp. 286–287.

J. L. Smith; Am. Jour. Sci., 1867, [2], xliii, pp. 66-67.

C. T. Jackson; Am. Jour. Sci., 1867, [2], xliii, pp. 280-281.

Iron. Irregular fragment with one face cut. Very coarsely crystalline. Called the Aeritopos meteorite by Prof. Shepard. Weight, 41.5 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 36. **Auburn, Macon Co., Alabama.** Found in 1867. Museum number, 4417.

C. U. Shepard; Am. Jour. Sci., 1869, [2], xlvii., pp. 230-233.

J. L. Smith; Am. Jour. Sci., 1870, [2], xlix, p. 331.

Iron. Irregular fragment, much rusted, and one side partially polished. The meteorite seems to be made up of a mass of granular concretions. After polishing a face of this meteorite Prof. Shepard says:

"The face, on being subject to the action of dilute nitric acid, gave me a series of markings altogether new. They are extremely fine and delicate in their dimensions, and require a strong light with the aid of a microscope to be seen with distinctness. The first character that displays itself is somewhat that of a mesh or network, and arises from the polygonal boundaries of the granular concretions. The areas within these lines or edges (which are exceedingly thin) have a glittering luster when held at a fixed angle to the light, though this angle often varies for different concretions, as in the case of a polished surface of coarse grained calcite or fluor. The second character that arrests attention in examination, is the finely striated surface of each concretion,—one set of lines being perfectly straight and equi-distant, as in calcite and labradorite, while a second set, but less distinct, cross these at right angles. The final peculiarity of the markings consists in this,—that these fine striæ are wholly made up of dots or beads, which are arranged in almost absolute contact, and are therefore to be regarded as consisting wholly of sections of rhabdite needles, while on the other hand, the mesh-like markings, first noticed, are composed of plates of schreibersite."

Weight, 24.92 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 37. **Pultusk, Sielce Nowy, Poland.** Fell at 7 p. m., Jan. 30, 1868. Museum numbers, 3352 (*c*), 3759 (*a*) and 4121(*b*).

G. Werther; Schrift. Konigsberg Gessel., 1868, ix, pp. 35-40.

G. vom Rath; Neues Jahrb. Min., 1869, pp. 80-82.

C. Rammelsberg; Mon. Berlin Akad., 1870, pp. 448-452.

a. Stone. One face polished, showing numerous glistening iron grains. The rest of the specimen is covered by a dull, brown crust. Weight, 100 grams.

[*By exchange with Prof. C. U. Shepard.*]

b. Part of a smaller individual with one side polished, the others showing crust. Weight, 11 grams.

[*By exchange with Yale College.*]

c. Part of a still smaller individual; one side polished and the others mostly covered with crust. Weight, 7.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 38. **Ovifak, Island of Disko, Greenland.** Found in 1870. Museum numbers, 3345 (*a* and *b*) and 4412 (*c*).

A. E. Nordenskjöld; K. Vet-Akad. Förh., 1870, p. 873; (see translation in Geological Magazine, 1872, [1], ix, p. 518.)

J. Lorenzen; Zeit. Deut. Geol. Gesell., 1883, xxxv, pp. 695-703.

G. A. Daubrée; Compt. rend., 1877, lxxxiv, p. 66; lxxxvii, p. 911.

J. L. Smith, Ann. Chemie. Phys., 1879, [5], xvi, pp. 452-505.

a. Native iron, formerly supposed to be of meteoric origin. Taken from basaltic rocks. Irregular, much rusted, piece appearing somewhat granular. Weight, 430 grams.

[*By exchange with Prof. J. L. Smith.*]

b. A small slab of the same, polished on both sides. Weight, 45 grams.

[*By exchange with Prof. J. L. Smith.*]

c. Fragment of the same, much rusted. Weight, 14.5 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 39. **Searsmont, Waldo Co., Maine.** Fell at 8:15 a. m., May 21, 1871. Museum number, 4409.

C. U. Shepard; Am. Jour. Sci., 1871, [3], ii, p. 133.

J. L. Smith; Am. Jour. Sci., 1871, [3], ii, pp. 200-201.

a. Stone. Gray and crumbling. One side shows a black spongy crust which is much thicker than the crust usually seen on meteorites. Weight, 0.83 gram

b. Smaller fragment, also showing crust on one side. Weight, 0.5 gram.

[*By exchange with Prof. C. U. Shepard.*]

No. 40. **Waconda, Mitchell Co., Kansas.** Found in 1874. Museum number, 3342, (*a*) and 3762 (*b*).

C. U. Shepard; Am. Jour. Sci-, 1876, [3], xi, pp. 473-474.

J. L. Smith; Am. Jour. Sci., 1877, [3], xiii, pp. 211-213.

a. Stone. Light gray, friable, clay-like mass containing very little iron. One side with a dull black crust. Weight, 72 gram.

[*By exchange with Prof. J. L. Smith.*]

b. Stone. Light gray fragment without crust. One face polished, showing considerable iron in two places. Weight, 72 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 41. **Mejillones, near the Desert of Atacama, South America.** Found in 1874. Museum number, 4695.

Iron. Small pieces of cut slab.

[*By exchange with Prof. C. U. Shepard.*]

No. 42. **Butler, Bates County, Missouri.** Found in 1874. Musenm number, 3357.

G. C. Broadhead; Am. Jour. Sci., 1875, [3], x, p. 401.

J. L. Smith; Am. Jour. Sci., 1877, [3], xiii, p. 213.

A. Brezina; Sitz. Akad. Wiss., 1880, lxxxii. Oct. Heft.

Iron. Thin slab with one face polished and etched, showing large and well marked Widmannstättian figures. The specimen contains a small nodule of triolite.

"It was noticed that the greater part of the iron had an even dull appearance, but in this lustreless iron gray part lay numerous—in part individual, in part grouped together—lamellæ, of which four differently directed systems appear on the sections. The lamellæ together form a skeleton—an octahedral skeleton. The groundmass, though lustreless and structureless, shows a peculiar play of light; its hardness is remarkably low, a little below 4, being distinctly scratchd by fluor."*

Weight, 104 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 43. **Iowa County, Iowa.** Fell at 10:30 p. m., Feb. 12, 1875. Museum number, 3359.

A. W. Wright; Am. Jour. Sci., 1875, [3], ix, pp. 459–460; 1875, [3], x, pp. 44–49.

*Walter Flight; A Chapter in the History of Meteorites, p. 187.

N. R Leonard; Am. Jour. Sci., 1875,[3], x, pp. 357–363,
J. L. Smith; Am. Jour. Sci., 1875,[3], x, pp. 362–363.
C. W. Irish; An Account of the Detonating Meteor of Feb. 12, 1875, Daily Press Job Printing Office, Iowa City.
G. A. Daubrée; L'Institut, 1875, (Nos. 105–122), p. 38.
C. W. Gümbel; Sitzungsber. Wiss. München, 1845, v. p. 313.

Stone. A complete individual, in the form of a parallelo gram, 3 inches by 2½ and 1 inch where thickest. Nearly completely covered with a dull black crust, some of the fractures showing crust partially formed. One end cut, showing compact, rather dark gray stony substance with many iron grains sprinkled through it. Similar in appearance to the Pultusk and to the more recent Winnebago meteorites.

Weight, 306.66 grams,

[*By exchange with Prof. J. L. Smith.*]

No. 44. **Santa Catarina, Rio San Francisco do Sul, Brazil.** Known in 1875. Museum numbers 4415(*a*) and 4692(*b*).
Guignet and Almeida; Comptes Rendus, 1876, lxxxiii, pp. 917-919.

a. Iron. A small fragment with one side polished. Weight, 18.35 grams.

b. A smaller fragment of the same. Weight 7.071 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 45. **Warrenton, Warren County, Missouri.** Fell Jan. 3, 1877. Museum number, 3347.
J. L. Smith; Am. Jour. Sci., 1877,[3], xiii, p. 243; 1877, [3], xiv, pp. 222–224.

a. Stone. Bluish-gray, soft, clay-like mass, with very little iron. A spongy blue-black crust on one side.
Weight, 13 grams.

b. Similar fragment, showing a small area of crust.
Weight, 9.5 grams.

c. A smaller fragment. No crust. Weight, 5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 46. **Cynthiana, Harrison County, Kentucky.** Fell at 4 p. m. Jan. 23, 1877. Museum number, 3343.
J. L. Smith; Am. Jour. Sci., 1877,[3], xiii, p. 243; 1877, [3], xiv, pp. 224–227.

a. Stone. Dull gray, with white grains and some iron particles. One side with a dull black crust partially full of pittings. Another side polished. Weight, 31.5 grams.

b. Smaller fragment of the same, showing crust on one side. Weight, 8 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 47. **Sarbanovac, Soko-Banjia Alexinatz, Servia.** Fell at 2 p. m., Oct. 13, 1877. Museum number, 4407.

E. Döll; Verhandl. d. K. K. Geol. Gesell., 1877, No. 16, p. 283.

S. M. Losanitch; Berichte d. Deut. Chem. Gessel., 1878, xi, p. 96.

Stone. Light gray fragment, with dark gray grains and some iron particles. No crust. Weight, 1.75 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 48. **Casey County, Georgia.** Found in 1877. Museum number, 3354.

A. Brezina; Stizber. Akad. Wiss., 1880, lxxxii, Oct. part.

Iron. Thin slab with one side polished and etched, but showing no Widmanstättian figures. Weight 36.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 49. **Estherville, Emmet County, Iowa.** [**"The Perry Meteor."**] Fell at 5 p. m., May 10, 1879. Museum numbers, 3058 (*a* to *e*), 4125 (*f*) and 4128 (*g*).

S.F. Peckham; Am. Jour. Sci., 1879 [3], xviii, pp. 77-78.

C. U. Shepard; Am. Jour. Sci., 1879 [3], xviii, pp. 186-188.

J. L. Smith; Am. Jour Sci., 1880, [3], xix, pp. 459-463, 495. (Prof. Smith's account was also published in the Eighth Annual Report of the Geol. and Nat. Hist. Survey of Minn., pp. 176-180.).

S. Meunier; Comptes Rendus, 1882, xciv, pp. 1659-1661.

M. E. Wadsworth; Mem. Mus. Comp. Zool., 1884, vol. xi, pt. I, pp. 97-101.

a. This is the second largest of the pieces that have been found. It was discovered two miles west of the largest piece, which weighed 437 pounds, and originally weighed 170 pounds.

"The masses are rough and knotted like large mulberry calculi, with rounded protuberances projecting from the surface on every side; the black coating is not uniform, being most marked between the projections. These projections have sometimes a bright metallic surface, showing them to consist of nodules of iron; and they also contain lumps of an olive-green mineral, having a distinct and easy cleavage. The greater portion of the stony material is of a gray color, with this green mineral irregularly distributed through it. * * * * * * The masses are quite heavy and vary much in specific gravity in their different parts; but the average can not be less than 4.5. When broken one is immediately struck with the large nodules of metal among the gray and the green stony substances, some of which will weigh 100 grams or more. In this respect the meteorite is unique, it differing entirely from the mixed meteorites of Pallas, Atacama, etc., or the known meteoric stones rich in iron; for in none of these has the iron this nodular character. * * * * * The constitution of this meteorite, so far as I have been able to make it out, is therefore as follows: Bronzite, abundant; olivine, abundant; nickeliferous iron, abundant; troilite in moderate quantity; chromite, in minute quantity; silicate, not yet well determined."* This specimen is a large irregular mass, much rusted, and one end has been sawed off leaving a polished surface.

Weight, 60,210 grams (132¾ pounds.)

[*Purchased for the Museum by Prof. E. J. Thompson*]

b. Rough irregular pieces. Two sides are cut; another shows crust. Weight, 215 grams.

[*Purchased by for the Museum Prof. E. J. Thompson.*]

c. Irregular piece, one side cut. Weight, 41 grams.

[*Purchased for the Museum by Prof. E. J. Thompson.*]

d. Irregular ragged piece, one side cut. Weight, 19.5 grams.

[*Purchased for the Museum by Prof. E. J. Thompson.*]

e. Rough ragged fragment. Weight 19.2 grams.

[*Purchased for the Museum by Prof. E. J. Thompson.*]

f. Small irregular piece of one of the iron nodules. One side polished and etched, showing Widmannstättian figures. Weight, 8 grams.

[*Presented by Prof. C. W. Hall:*]

g. Small fragments of peckhamite from the above meteorite. Weight 0.672 gram.

[*Purchased probably from Prof. J. L. Smith.*]

No. 50. **Lexington Co., South Carolina.** Found in May, 1880. Museum number, 4418.

*Am. Jour. Sci., 1880, [3], xix. This silicate is probably peckhamite.

C. U. Shepard; Am. Jour. Sci., 1881, [3], xxi, pp. 117-119.

Iron. Irregular fragment with three faces polished. One of them is etched, but shows Widmannstättian figures only indistinctly. Weight, 17.5 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 51. **Ivanpah, San Bernadino Co., California.** Found in 1880. Museum numbers, 4420 (*b*) and 4421 (*a*).

C. U. Shepard; Am. Jour. Sci., 1880, [3], xix, pp. 381–382.

a. Iron. Cuttings. Weight, 2.3 grams.

b. Small irregular fragment of iron. Weight, 1.98 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 52. **Brenham, Kiowa Co., Kansas.** Found in 1885. Museum number, 7240.

N. H. Winchell and J. A. Dodge; Amer. Geologist. 1890, v, pp. 309–312; 1890, vi, pp. 370–377.

G. F. Kunz; Science, 1890, xv, p. 359.—Trans. N. Y. Acad. Sci., 1890, ix, pp. 186–194.

a. Iron. A coarse, metallic sponge containing olivine, chromite and troilite.

"Metallic iron comprises somewhat less than one-half the meteorite, and it serves as a matrix in which are embraced amygdaloidal or roundish masses from the size of a pea to that of a musket ball, and larger, of the black and yellowish minerals which comprise nearly the whole of the rest of the mass." This mass originally weighed 211 pounds. "It was approximately globular, with a broad shallow depression that encircled it about half way. Its exterior is oxidized by long exposure, some of the mineral grains having been profoundly affected by the penetration of iron oxide." About 85 pounds have been cut off from one side of the mass, leaving a plane surface which has been figured in the American Geologist, vol. vi, plate vii.

Weight, 55,790 grams (123 pounds).

b. Slab cut from the above mass, about one inch thick and 42 inches in circumference. Weight, 9410 grams. Shown in plate vii, vol. vi, Dec., 1890, of the American Geologist.

c. Irregular mass with two sides polished; one has been etched and shows Widmannstättian figures; this surface also is figured in the American Geologist, vol. vi, p. 272. Weight, 2648 grams.

k. Wedge-shaped piece. 3½ inches long, 1½ wide and 2¼ thick at the large end. All the faces cut except one.

which is the largest and is covered by crust. Weight, 630 grams.

l. Irregular piece, with three sides cut, one partially cut, and the other with crust, Contains a large proportion of the black minerals. Weight, 630 grams.

m. Irregularly rectangular piece. Four faces cut; another shows crust. About 2½ inches by 2 by 1½. Weight, 570 grams.

p. Irregular ragged piece of metallic sponge. Most of the olivine has fallen out, but there is considerable of the black minerals present. Weight, 100 grams.

q. Ragged fragment, having some iron and considerable of black minerals. Weight, 28 grams.

r. Ragged fragment. There is considerable olivine and a small amount of the black minerals present. Weight, 17.7 grams.

s. Rusted, ragged fragment with considerable olivine. Weight, 12.7 grams.

t. Irregular fragment with a small amount of the black minerals and no olivine. Weight, 12 grams.

u. Ragged fragment; a small amount of the black minerals, but no olivine present. Weight, 11.8 grams.

v. Irregular fragment with considerable of the black minerals but no olivine. Weight, 11.3 grams.

w. Ragged sponge of iron containing nothing else. Weight, 9.6 grams.

x. Irregular rusted spongy fragment, having a little olivine. Weight, 9.1 grams.

y. Ragged fragment of iron containing nothing else. Weight, 8.9 grams.

z. Ragged fragment with considerable of the black minerals and very little olivine. Weight, 8.7 grams.

aa. Ragged, rusted fragment, Weight, 7.4 grams.

ab. Coarse cuttings, mostly iron. Weight about 4000 grams

ac. Finer cuttings. Weight, 1100 grams.

ad. Finest cuttings. Weight about 5500 grams.

No. 53. **Bandera Co., Texas. [Pipe Creek Meteorite.]** Found in 1887. Museum number, 7242.

A. R. Ledoux; Trans, N. Y. Acad. Sci., 1889, viii, pp. 186-187.

Stone. Slab, one fourth inch thick and five inches in circumference; both faces and two edges have been pol-

ished. Dark brown apparently porous groundmass holding black grains and irregular shining iron particles. Weight, 24.6 grams.

[*By exchange with Dr. H. Hensoldt.*]

No. 54. **Winnebago County, Iowa.** Fell at 5.15 p. m., May 2, 1890. Museum number, 7239.

G. F. Kunz; Trans. N. Y. Acad. Sci., 1890, ix, pp. 201–203.

J. Torrey and E. H. Barbour; Amer. Geologist, 1891, viii, pp. 67–72.

a. Stone. Large individual measuring about 13 inches in greatest diameter, and about 9 inches in the other directions. Covered by crust, except where it has been somewhat broken along the edges, and an area 7 by 3 inches on one side, from which a piece of the stone, not more than an inch thick, has been broken off. This is the 66-pound stone figured in the American Geologist, vol. viii, p. 68.

"This meteor is a typical chondrite, apparently of the type of the Parnallite group of Meunier, which fell February 28th, 1857, at Parnellee, India. The stone is porous, and when placed in water to ascertain its specific gravity, there is a considerable ebullition of air. The specific gravity on a fifteen-gram piece, was found to be 3.638. The crust is rather thin, opaque black, not shining, and, under the microscope is very scorious, resembling the Knyahinya (Hungary) and the West Liberty (Iowa) meteoric stones. A broken surface shows the interior color to be gray spotted with brown, black and white, the latter showing the existence of small specks of meteoric iron from one to two millimetres across. Troilite is also present in small rounded masses of about the same size. On one broken surface was a very thin scum of a black substance, evidently graphite, soft enough to mark white paper; a feldspar (anorthite) was likewise observed, and enstatite was also present."*

"The dead black scoriaceous crust when broken, reveals a light gray stone interspersed with innumerable dark particles of iron and globules of troilite, quite like the Iowa County stones in appearance. Thin seams and cracks occur occasionally filled with a substance that has somewhat the appearance of graphite, and small spheroidal masses of olivine are abundant."†

Weight, 29.820 grams (65.75 pounds.)

[*Purchased on the spot by H. V. Winchell, of the party on whose farm it fell.*]

b. Individual completely covered by crust. Weight, 961.5 grams.

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*Trans. N. Y. Acad. Sci., ix, p. 201.

† Amer. Geologist, viii, p. 67.

c. Fragment broken from the large individual (*a*). Shows a few minute dark veins or seams. About half the surface covered by crust. Weight, 450 grams.

d. Individual completely covered by crust, except a small area on one side. Weight, 75.8 grams.

e. Complete individual. Crust broken on edges in two or three places, and on one side it is thinner and rather glassy in appearance. Weight, 62.7 grams.

f. Individual completely covered by crust. Weight, 49.3 grams.

g. Irregular fragment. Two sides (or about half its surface) covered by crust. Weight, 48.6 grams.

h. Irregular individual completely covered by crust except where it has been broken off in a few places. Weight, 46.1 grams.

i. Roughly rectangular individual, about 1¾ inches by 1 by ¾; mostly covered by crust, but on one side the crust is imperfectly formed, as if a piece was here broken off a short time before striking the ground. One broken and partially polished. Weight, 45.3 grams.

j. Fragment more than half covered with crust. Weight, 40.5 grams.

k. Thin fragment about 2 inches long and 1¼ wide. Over half covered by crust. This is probably a piece from the large individual (*a*). Weight, 32.7 grams.

l. Complete individual. Weight, 31.8 grams.

o. Irregular piece covered by crust, except at one side, which is rusted. Another side has a comparatively thin crust. Weight, 29.1 grams.

r. Individual. Small area of crust gone from one edge. Weight 20.4 grams.

s. Complete individual. One end has a rough surface and thinner crust. Weight, 19.6 grams.

t. Small fragment from the large individual (*a*). Shows small area of crust. Weight, 18 grams.

u. Individual. Crust broken some on edges and thinner on one side, which has a rough surface. Weight 16.6 grams.

v. Complete individual. Weight 16.2 grams.

x. Individual. Crust spongy on one side. Weight 14.9 grams.

y. Fragment about half covered by crust. Weight 14.6 grams.

ab. Complete individual in the form of an irregular three-sided fragment, the base of which has a very spongy crust. Small pieces of the crust broken off in two or three places. Weight 12.3 grams.

ac. Fragment about half covered by crust; the part without crust is apparently somewhat rusted. Weight 11.7 grams.

ad. Apparently an individual with one end broken off. Weight 11.6 grams.

ae. Individual, crust gone from part of one side. Weight 10.5 grams.

af. Individual. One side is rough and has thinner crust. Crust cracked off somewhat on the edges. Weight 10.1 grams.

ag. Piece all covered with crust, excepting one end. Crust very thick. Weight, 8.8 grams.

ah. Individual. Two-thirds the surface is rough and has thinner crust. Weight, 8.6 grams.

ai. Irregular individual. Crust imperfectly formed on one side. Weight, 8.3 grams.

aj. Complete individual. Weight, 8.3 grams.

ak. Complete individual. Weight, 7.5 grams.

am. Complete indvidual. On one side the crust appears thin and very porous. Weight. 7.3 grams.

an. Irregular individual, with one side rough where the crust is thin. Weight, 7.1 grams.

ao. Complete individual. Weight, 7 grams.

aq. Fragment, one-third covered by crust. Weight, 6.7 grams.

ar. Piece about two-thirds covered by crust. Weight, 6.4 grams.

at. Individual with about one-third of the crust gone. Weight, 6 grams.

au. Individual with crust thin on one side. Crust broken off in a few places. Weight, 5.6 grams.

av. Irregular fragment nearly one-half covered by crust. Weight, 5.5 grams.

aw. Individual with small area of crust gone. Weight, 5.4 grams.

ay. Complete individual. Weight, 5.2 grams.

az. Individual with crust broken off in two places. One side rough and with thinner crust. Weight, 5.03 grams.

ba. Complete individual. Weight, 4.91 grams.

bb. Complete individual. Weight, 4.9 grams.
bd. Complete individual. Weight, 4.3 grams.
be. Complete individual. Weight, 4.3 grams.
bg. Complete individual. Weight, 4 grams.
bi. Complete individual. Small area of crust broken off. Weight, 3.6 grams.
bj. Piece covered by crust, except on one side. Weight, 3.4 grams.
bk. Complete individual. Weight, 3.3 grams.
bm. Individual with small area of crust broken off one end. Weight, 2.9 grams.
bn. Complete individual. Weight, 2.8 grams.
bo. Complete individual. Crust in places quite porous or spongy. Weight, 2.7 grams.
bp. Individual with crust broken off in several places. Weight, 2.7 grams.
bq. Fragment about one-third covered by crust. Weight, 2.4 grams.
br. Piece two-thirds covered by crust. Weight 2.2 grams.
bs. Complete individual. Weight, 2.2 grams.
bt. Irregular fragment about one-half covered by crust. Weight, 2.1 grams.
bu. Complete individual. Weight, 2.1 grams.
bv. Complete individual. Crust thinner on surface; rough on one side. Weight 2 grams.
bw. Complete individual. Weight 1.9 grams.
bx. Complete individual. Weight, 1.84 grams.
by. Individual with some of the crust gone from one edge. Weight, 1.78 grams.
bz. Complete individual. Weight, 1.72 grams.
ca. Complete individual. Weight, 1.66 grams.
cb. Individual with crust broken off in places from the edges. Weight, 1.56 grams.
cc. Complete individual. Weight, 1.54 grams.
cd. Small irregular fragment showing no crust. Weight, 1.53 grams.
ce. Piece two-thirds covered by crust. Weight, 1.51 grams.
cf. Complete individual. Weight, 1.45 grams.
cg. Complete individual. Weight, 1.3 grams.
ch. Complete individual with rough surface. Weight, 119 grams.
ci. Complete individual. Weight, 1.09 grams.
cj. Complete individual. Weight, 1.03 grams.

ck. Complete individual. Weight. 0.98 gram.

cl. Complete individual with quite porous or spongy crust. Weight, 0.96 gram.

cm. Individual. Crust quite thick, and a small area of it broken off one end. Weight, 0.87 gram.

cn. Fragment one-third covered by crust. Weight, 0.85 gram.

co. Complete individual. Weight, 0.75 gram.

cp. Complete individual. Weight, 0.55 gram.

cq. Irregular fragment without any crust. Weight, 0.37 gram.

[*Purchased on the spot by N. H. Winchell from parties who found them.*]

No. 55. **Washington County, Kansas.** Fell June 25, 1890. Museum number, 7241.

Stone. Dark ground mass with some white grains and glistening metallic particles. Very heavy and rich in iron. Weight, 562 grams.

[*Purchased through H. V. Winchell.*]

No. 56. **Diablo Canon, Arizona.** Found March, 1891. Museum number, 7947.

Iron. Entire individual. Lenticular mass. Weight 12¾ ounces. Some pieces contained diamonds.

[*By exchange with A. E. Foote.*]

No. 57. **Diablo Canon, Arizona.** Found March, 1891.

Siliceous iron associated with the last. Weight, 7¾ ounces. Museum number, 7948.

A. E. Foote; Am. Jour. Sci., vol. xlii, p. 413, 1891.

About 1700 pounds have been found. The diamonds were discovered in cutting, by Prof. G. A. Kœig.

No. 58. **Fayette County, Texas. (La Grange Meteorite.)** Found in 1878 by farmers, but brought to light by Mr. H. Hensoldt in 1888. Museum number, 7949.

Chondritic stone, slab, length 22 in., width 11 in., ⅞ in. thick, weight, 16 pounds. [*By exchange with Henry A. Ward.*]

Howell; Science, Feb. 3, 1888, p. 55. J. E. Whitfield and G. P. Merrill; Am. Jour, Sci., 1888 [3] vol. xxxvi, p. 113.

Total weight about 146 kilos. * * *

"To the unaided eye the chondritic structure is not distinctly marked, a broken surface showing a fine grained and evidently crystalline-granular rock, very compact, of a greenish-gray color and thickly studded with small metallic points with a brassy lustre. A polished surface shows the stone to be composed of small chondri rarely over 2 mm. in diameter, thickly and firmly compacted in a fine granular groundmass. Throughout the entire mass are thickly distributed innumerable small irregular flecks of a steel-gray, brassy and bronze-yellow color, presumably native iron and pyrrhotite."

VIII.

NOTES ON THE PETROGRAPHY AND GEOLOGY OF THE AKELEY LAKE REGION, IN NORTHEASTERN MINNESOTA.

BY W. S. BAYLEY,

U. S. Assistant Geologist, Lake Superior Division.

Upon the request of the writer, a number of specimens of the rocks collected by members of the Minnesota Geological Survey from the region adjacent to Chub (Akeley) lake, in Sec. 29, T. 65 N., R. 4 W., Minn., were kindly furnished him for microscopic study by Prof. N. H. Winchell, State Geologist of Minnesota. At the time the request was made there was no intention of publishing the results of this study, but when the microscopical features of the different rocks were compared with each other, and with their structural relationships, it was discovered that an entirely new light was thrown on the latter, and that these must be given a different interpretation from that given them in the 16th and 17th Minnesota reports. Consequently, it has been thought wise by Prof. Winchell to make public what is now known concerning the rocks in this vicinity, in order that the geology outlined in the reports may be appreciated with a little more clearness than has heretofore been possible.

Since some of the conclusions reached by the Minnesota geologists, after study of the hand-specimens of these rocks, are here shown to be erroneous, in consequence of a mistaken supposition with reference to their nature, it would seem proper to emphasize once more the danger of generalizing concerning the relations of pre-Cambrian rocks before having subjected them to a thorough microscopical investigation.

I desire to thank Prof. Winchell for his courtesy in providing the material asked for, and for his kindness in affording this means for the publication of my article.

(1) Occurrence and Description of Specimens Mentioned in the 16th Report.

1327. (16th Ann. Report, p. 80). South and a little east of the NW corner Sec. 24, T. 65 N., R. 4 W.

At this place is a low northward facing Animikie bluff in which the strata dip southeastwardly about 12°. It is made up of ore on top and of alternating gray grit and sandstone, with some ore and chert, below (1327).*

Under the microscope 1327 is seen to be a well defined quartzyte, composed of rounded quartz-grains, contiguous to some of which may be detected enlargements. The inclusions are fine dust-like particles and liquid enclosures. Between the quartz-grains was once an abundant cement, but this has been changed to a crystallized aggregate of fine needles of hornblende and fibres of chlorite, that often unite to form radiating spherulites. in the centers of some of which are little irregular masses of magnetite. These spherulites are scattered here and there along the lines separating adjacent quartz-grains. Occasionally they are confined entirely to these interstitial spaces, but more frequently their fibres penetrate the quartz-grains on both sides. while sometimes a spherulite may be entirely surrounded by quartz (Fig. 1). Were it not quite certain that the rock is

FIG. 1.
Fragmental quartzyte, with cementing material changed to chlorite and fibrous hornblende. No. 1327,x27.

fragmental, from the relations existing between the hornblende needles and the quartz, we would be led to regard the latter as

*The descriptions of occurrences are abstracted from the Minnesota reports, where they appear at greater lengths.

younger than the former. As the case stands, we must conclude that the spherulites have formed since the rock was laid down.

1329. (16th Ann. Report, pp. 81-82.) About 250 paces west of NE corner Sec. 22, T. 65 N., R. 4 W.

This specimen is a sample of a great dyke that cuts the gneiss underlying the rocks above mentioned. 1329 does not correctly represent the dyke, but it is the only sample that has been furnished. It is a very coarse-grained olivine-diabase, with long lath-shaped crystals of a plagioclase near andesine, large grains of light-colored olivine, and interstitial, allotriomorphic dark pink, slightly pleochroic augite, with much irregular magnetite in and around the augite. This last named mineral is quite fresh, except in small areas immediately next to feldspars, where it is slightly chloritized. The rock resembles very strongly the substance of the great dykes everywhere cutting the Animikie in the lake Superior region.

1334 and 1335. (16th Ann. Report, p. 83.) SW ¼ Sec. 21, T. 65 N., R. 4 W.

The greenstone represented by 1329 extends southward to near the south line of Sec. 21, where it is evident that the greenstone has given way to the Animikie carrying magnetite. The most southern identifiable portion of the greenstone is represented by 1334. Beyond this there is a transition to a rock represented by 1335, which is heavily bedded. It dips south at 45° and apparently underlies the iron beds (1336). The rock has not the characteristics of an eruptive, but it appears to have those of a basic sedimentary bed which has been metamorphosed. Such a rock has not before been seen in Minnesota. 1334 and 1335 occur in two bluffs on the opposite sides of a narrow E. and W. lake.

1336. (16th Ann. Report, p. 82.) NE ¼, NE ¼ Sec. 29, T. 65 N., R. 4 W.

"This ore is well characterized olivinitic, magnetic, granular, the yellowish waxy grains of olivine being mingled rather uniformly with the grains of magnetite."

1334, which, if the beds all dip south, is the lowermost member of this interbedded series, is mainly an aggregate of very small grains of an almost colorless augite, surrounding here and there a larger grain of the same mineral. The smaller grains are very irregular in shape, while the larger ones are long and narrow, as if vertical sections of crystals flattened parallel to their basal planes. There is a rude parallel ar-

rangement of the grains so that the rock possesses a kind of stratified structure. In addition to the augite there are in bands in the section small grains of a greenish-brown hornblende. These are intermingled with the grains of the augite mosaic, and like these are rudely arranged in parallel directions. A few grains of magnetite scattered through the mosaic and an occasional grain of quartz complete the list of the rock's constituents. There is no evidence of any kind that the rock was ever clastic. It appears rather to be a modified eruptive. The augite mosaic has certainly resulted from the fracturing of large grains of pyroxene and the movement of the fractured parts from their original positions. In one portion of the slide this process may actually be seen in operation. A large grain of augite is granulitized around its edges, while its interior is crossed by many irregular lines of fracture, which divide the grain into hundredsof smaller ones. The slightest movement would suffice to transform this broken grain into an augite mosaic exactly like that elsewhere in the section. 1335, into which 1334 is supposed to grade, is not very different in its structure from 1334. It is an aggregate of tiny rounded grains of almost col orless augite, and grains and tiny lath-shaped crystals of plagioclase forming a mosaic in which lie much altered large grains of augite, changed on their edges to greenish-brown hornblende and peppered throughout with dust-like grains of magnetite. A few grains of the hornblende are also discovered in other parts of the slide, but they occur in such relations to the other minerals as to leave no doubt that they are derived from large grains of augite (Fig. 2). The composition, as well as

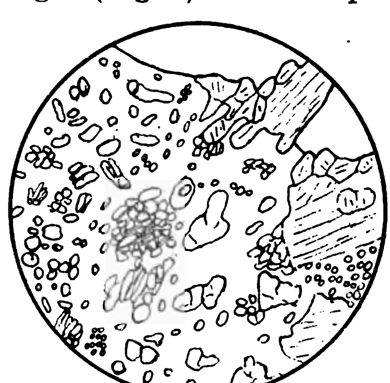

FIG. 2.

Granulitic gabbro, with large grains of green hornblende and small rounded ones of augite in a groundmass of plagioclase that appears in ordinary light to be a homogenous mass. No. 1335,x87.

the structure of the rock, places it among the granulitic gabbros so well described by Judd,* and ascribed by him to the movement of a gabbro rock mass, while in the pasty condition just prior to complete solidification. 1336, the iron ore above 1335, is mainly an aggregate of olivine and augite, and irregular grains of magnetite. The latter mineral is in large pieces scattered between the other two, especially between the grains of olivine, and in small rounded grains included in the latter. The large pieces are apparently secondary, while the small round grains are probably original. The olivine is older than the pyroxene. It is in round grains of a yellowish green color included in large pieces of augite, and it also forms a groundmass of interlocking grains in which the plates of pyroxene lie. These latter are large and are very irregular in outline. They include olivine and stretch far out into the interstices between the grains of the groundmass. The color is bright green. There is no noticeable pleochroism and the extinction is about 35° (Fig. 3).

FIG. 3.
"Ore" in gabbro, consisting of olivine (stippled) hornblende (vertically striated) and magnetite (solid black). No. 1336,x27.

This rock like the others (1334 and 1335) is undoubtedly a modified eruptive. It certainly is not fragmental, nor is there any proof that it is a changed fragmental. No metamorphic rocks of this kind have ever been described, nor is it plain how such might be formed, except by complete fusion and recrystallization, in which case the result would not be distinguishable from an original eruptive. Fig. 3. shows the structure of the ore.

* Quart. Jour. Geol. Soc., 1886, p. 49.

1340 and 1341. (16th Ann. Report, p. 85.) The quartzyte with which the ore is associated is well developed a little to the west of 1336. Here it dips 48° to the south, the quartzyte and magnetic quartz-schist being from 140 to 150 feet thick, and the associated olivinitic ore beds perhaps 50 feet. Interbedded with one of the quartzyte layers (1340) is a bed of gabbro (1341), which varies rapidly in its structure from the coarse grain of the ordinary gabbro to the fine grain of the rock called "muscovado" in the 15th, 16th, 17th and 18th Annual Reports.

1340. The so-called quartzyte, is not a fragmental rock, but is one composed of interlocking quartz-grains, including magnetite. (Fig. 4.) The latter, which is the older of the two

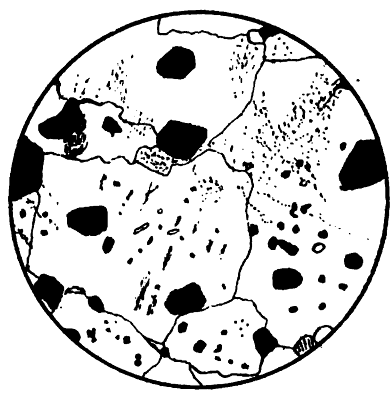

FIG. 4.
Crystallized quartzyte, associated with "ore" and granulitic gabbro. No. 1340.x27.

components is often in well marked octahedrons enclosed in the quartz, but more frequently it is in rounded grains, either surrounded by a quartz individual, or situated between several of them. In the latter case the grains are slightly altered on their edges to a brownish earthy product, probably limonite, or to a green decomposition product, either chlorite or hornblende. The quartz interlocks by sutures that are perhaps not quite as irregular on the whole as the sutures of granitic quartz, but they are too irregular to be regarded as due to any cause but the crystallization of the quartz *in situ*. A comparison of fig. 4 with fig. 1 will show plainly the difference in structure between this crystallized quartzyte and the fragmental quartzitic sandstone of the Animikie.

1341. The gabbro interbedded with the crystallized quartzyte is in an intermediate phase between the coarse grained normal olivine gabbros and the granulitic varieties, in which the

pyroxene occures in small rounded grains. The olivine is in the ordinary form. The plagioclase is in irregular grains, with a tendency to the lath-shaped forms of diabasic feldspar. Its gabbroitic character is evinced in the abundance of dust-like particles scattered through it, and especially by their thick accumulation toward the centers of all grains. The pyroxene is a light-colored augite, thickly crowded with magnetite grains, small masses of limonite and tiny plates of brown biotite. Some of the augite is in ophitic plates between the feldspars, but most of it is in little rounded grains. The magnetite, nearly all of which is secondary, is thickly strewn through the section in long irregular grains in and between the other constituents, especially the augite and olivine, and in tiny rounded grains in the augite and the plagioclase.

(16th Ann. Report, pp. 86-87.) The great quartzyte of which No. 1340 is a sample, "is near the top* of the Animikie, and, since it is a new feature in the northeast part of Minnesota, it deserves a name. It apparently occupies the same horizon as the quartzyte at the head of Wauswaugoning bay. Because of the association with it of iron beds it has been called "Pewabic quartzyte."

1343 and 1346. Near the center of the NE ¼ of the SW ¼ of Sec. 25, T. 65 N., R. 5 W., the Pewabic quartzyte is again met with (1343,) dipping 55° S., and further north occurs greenstone (1345) quite like that in sections 21 and 29, T. 65 N., R. 4 W., (viz., 1334 and 1335) but approaching a little more closely to the rock called "muscovado" in other reports.

1347. (16th Ann. Report, p. 88.) The best sample of "muscovado" comes from the shore of Muscovado lake, in Sec. 36, T. 65 N., R. 5 W.

1343, which is said to be a sample of the Pewabic quartzyte, is an olivinitic rock which is probably but a very basic phase of gabbro, just as the olivine bombs of basalts are nothing† but very large accumulations of olivine and other basic minerals in the surface equivalents of the gabbros. It is composed almost exclusively of olivine and quartz. The latter is probably the younger component as it occurs in subangular grains, often entirely surrounded by olivine, to whose contours it appears to adapt itself. It includes tiny grains of magnetite, rounded

*In Bulletin No. 6 of the Minnesota Geological Survey (p. 125) this quartzyte is put at the bottom of the Animikie, and it is no longer regarded as the equivalent of the Wauswaugoning quartzyte.

†Bauer: Neues Jahrb. für. Min., etc., 1891. II, p. 200.

ones of olivine, and some small acicular, almost colorless crystals that are thought to be pyroxene. The olivine constitutes over ninety per cent. of the entire rock. It is in closely crowded, mutually interfering, pale yellowish-green grains, containing a few magnetite inclusions and some that appear to be of glass. Occasionally an olivine grain may be included within a quartz grain, but usually the olivine forms a compact granular groundmass in the occasional interstices of which the quartz has recrystallized. Another mineral occurring in the rock in very small quantity is a bright green pyroxene that is very slightly pleochroic. The fine series of striations apparent on it indicate a diallage. This mineral is found only in very small pieces between the olivines, or between this mineral and quartz. It is probably more common in the latter position than in the former. It is undoubtedly younger than the olivine and older than the quartz. The constitution and structure of the rock point directly to the gabbros as its nearest relatives.

1345 is a granulitic gabbro, composed of rounded grains of augite and plagioclase, the latter of which often include the former, and large plates of brown hornblende. The hornblende is very strongly pleochroic and is present in small flakes scattered between the augite grains, and in large ones in areas where the augite is most thickly accumulated. From the fact that many of the grains of augite in the section are partially changed to green and brown hornblende, it is inferred that all of this mineral is secondary. Its contours are very irregular and the peripheral portions of the larger plates are granulated exactly as is the augite.

1347, like 1334 and 1335, is a granulitic gabbro, but unlike the latter two rocks it contains an abundance of hypersthene and but very little olivine. All the components are beautifully fresh. The plagioclase is in very irregular pellucid grains, enclosing magnetite and hypersthene, besides a few glass inclusions. The hypersthene forms more or less rounded grains lying between the plagioclase grains, and sometimes included in them. It is pleochroic in deep pink and light green tints, and it includes a few magnetite grains. In many portions of the section the grains are isolated, but in other portions they unite to form accumulations, between the grains of which large masses of magnetite lie. The olivine, when present, is in large irregular grains, very much decomposed with the production of much magnetite.

The relation of this rock to a gabbro is too clear to need emphasizing. The components are those of the gabbros, while the structure corresponds exactly to that of the granulitized varieties.

DISCUSSION.

Of the rocks above described, 1327 is a fragmental quartzyte, 1329 a diabase, 1334, 1335, 1345 and 1347 are granulitic gabbros, 1341 is an intermediate phase between the normal gabbros and the granulitic varieties, 1336 a very basic aggregate of gabbro components, 1343 a similar basic aggregate with the addition of quartz, and 1340 a crystallized quartzyte.

In the 16th Annual Report of the Minnesota Geological Survey, 1327 is called a chert, 1336 an Animikie bed (presumably quartzyte) carrying ore, 1340 a quartzyte (presumably fragmental), 1343 quartzyte (Pewabic quartzyte), and 1345 and 1347 "muscovado."

The most evident results of the microscopic study of the rocks are with respect to their nature. 1327 is not a chert, but like all the other non-eruptive Animikie beds described, it is a sedimentary clastic rock.

The "muscovados" that have so frequently been mentioned in the reports as very peculiar basic rocks whose true nature is unknown, have been learned to be granulitic phases (sometimes quartzitic) of the very common gabbros so prevalent in northeastern Minnesota.

The "Pewabic quartzyte" (1343) and its associated ores (1336) are about as far removed from being quartzytes as possible. Instead of being acid fragmental rocks, most of them are basic crystalline ones, and from their very nature they may safely be considered as phases of gabbro.*

From the single section of 1340 it is not possible to learn much. However, the rock is not a fragmental quartzyte like the quartzyte of the Animikie beds, and consequently cannot be regarded as the equivalent of fragmental quartzytes existing at other places in the lake Superior basin. If we may be permitted to interpret the result of the study of section 1340 by means of the knowledge gained during the investigation of a suite of specimens collected from the Akeley lake region by the United States Geological Survey, we must conclude that

* In this paragraph it is not intended to deny the possibility of any of the so-called Pewabic quartzytes being true fragmentals. It is merely asserted that much of this rock in the Akeley lake region is a phase of gabbro. and that none of it in this neighborhood is fragmental.

this rock, though a completely crystallized quartzyte, is nothing more nor less than an extreme phase of the gabbro. In other words, it is a completely altered gabbro rather than an independent rock species, and hence it must be classed with the gabbro overlying the Animikie and not with the Animikie fragmentals.

From the above statements it is quite clear that some of the conclusions reached by the Minnesota geologists with respect to the relations of the Akeley lake ores to the Animike beds must be modified. From the mere fact that the former dip south at high angles (30°–55°), while all of the Animike beds are only moderately inclined (12°–25°), it might be argued that the two series are different. A stronger argument, however, is discovered when we learn that none of the beds belonging to the former series are fragmental, while all of those of the Animike are either clastic or but slightly altered diabases. Moreover the Akeley lake ores are underlain by modified gabbro, while the ores themselves are probably phases of the same rock, which extends from this place southward for many miles as a typical olivine-gabbro. We must then class the ores, and even much of the rock called "Pewabic quartzyte" with the gabbros. Even though some of the rock called "Pewabic quartzyte" may be a true quartzyte in the Animikie, it is evident that it is not of as great importance for correlation purposes as has been supposed.

Some of the conclusions published in the 16th report (pp. 84, 85) of the Minnesota Survey, must thus be modified before they can be accepted as correct. Without entering further into the discussion of the various conclusions in detail, it will prove sufficient for the present purpose to state them briefly in their modified forms. The changes, which the writer thinks are necessitated by the knowledge of the true nature of the rocks concerned, may be learned by comparison of the original conclusions* as published in the Minnesota report, with those here given.

1. The ore beds of the Akeley lake series belong with the overlying gabbro, and not with the Animikie.

2. The iron-bearing rock is a phase of the gabbro into which it passes above.

* The numbering of the conclusions corresponds with that used in the Minnesota report.

3. The bedded rocks of the iron belt are granulitic gabbros, and consequently are eruptives, and not changed sedimentaries.

4 and 5 may stand unchanged, if by quartzyte is not understood a fragmental rock.

6. The rocks interbedded with the ores are special phases of gabbro.

7, 8 and 9 remain unchanged so far as the conclusions are concerned.

10. Since the so-called Pewabic quartzyte of the Akeley lake region is in most cases a gabbro, it cannot be correlated with quartzytes in the Animikie in other regions. In the Akeley lake region it is certainly near the bottom of the gabbro.

(II) Occurrence and Description of Specimens Mentioned in the 17th Report.

451 (H) and 452 (H). (17th Ann. Report, p. 107.) NW¼ Sec. 28, T. 65 N., R. 4 W.

Southeast of 1334 and 1335, and east of 1336, 1340 and 1341, and nearly on their strike, are beds of Animikie (?) slate and ore, dipping at 60°–75°, and lying upon a biotitic gabbro, which has slightly metamorphosed their lowest quartzitic and ore layers. Nos. 451 and 452 show the changes and gradation of the Animikie beds as they become crystalline and pass through metamorphosed strata into the greenstone.

453 (H). (17th Ann. Report, p. 108.) is another specimen of the Animikie from a drill hole a little to the south of 451 and 452.

451 (H), like the rocks to the west of it, is a gabbro, and not a fragmental rock in any sense of the word. Its structure, like that of 1341, is intermediate between that of the true gabbros and that of the granulitic varieties. It contains large plates of almost colorless augite and of strongly pleochroic hypersthene, surrounded by an aggregate of rounded grains of the same minerals, flakes of brown biotite and irregular grains of colorless plagioclase. In the immediate neighborhood of the larger pyroxenes the small grains of this mineral are orientated to correspond with the orientation of the larger ones, from which they are separated by the plagioclase. The biotite is in large flakes with strong pleochroism in bright yellow and

dark bronzy tints. that lie within the large grains of pyroxene and between the smaller grains, and in very small ill-defined masses within the larger grains of both the augite and the hypersthene. It is also found included in the plagioclase, and occurring between the feldspar grains. Of the plagioclase nothing need be said save that it is the youngest of the original components, the biotite being regarded as secondary. The arrangement of the various constituents in a rudely parallel manner produces an apparent stratification, which no doubt was the phenomenon that led to the supposition that the rock is part of the sedimentary Animikie. The microscope shows clearly that this is not the case. The rock is surely eruptive, and is a phase of the great gabbro flow.

No. 452(H), which was thought to represent a more metamorphosed phase of 451, is a crystallized quartzyte, like 1340, which lies to the west of it. That it should be classed as an extremely acid phase of the gabbro is indicated by the existence in it of large masses of augite and secondary green hornblende. When these minerals are in contact with the quartz grains the latter are bounded by a fringe of very fine needles that are probably hornblende.

No. 453 H, also supposed to be an Animikie fragmental by the Minnesota geologists, is very similar to 1336 and 1343 in structure. In composition, however, it differs from these in that the pyroxene is mainly hypersthene. This is present in very large plates, including small rounded grains of a light green augite and bright green masses of hornblende, besides numerous grains of magnetite, that are so abundant as to make the rock nearly as much of an ore of iron as 1336. From the nature of the rock it is quite plain that it is a phase of gabbro.

454 (H.) (17th Ann. Report, p. 109.) "In the NW ¼ Sec. 35, T. 65 N., R. 5 W., is a knoll of Animikie quartzyte. * * * It dips south about 75° and strikes east and west. Across the valley which lies to the south side of it, is found gabbro."

This rock, like 452 (H,) is a crystallized quartzyte, composed of interlocking grains of quartz, including large numbers of magnetite grains. In addition to the included magnetite there is an abundance of this mineral between the quartz grains. A few flakes of hornblende or chlorite occur between the quartzes and long slender needles of some opaque mineral extend from the edges of the included magnetites far out into the surrounding substance. The most important fact in connection with these three rocks is that the one (451 H) farthest removed from

the underlying (metamorphosing?) greenstone is least like a sedimentary rock. Consequently those nearest the greenstone (452) can not have been formed from it by the metamorphosing action of the latter—using "metamorphosing" in the sense in which it is used in the Minnesota report.

455 (H), 456 (H), and 458 (H.) (17th Ann. Report. p. 109-110.) NW ¼ Sec. 35, T. 65 N., R. 5 W. The knoll in which 454 (H) is found extends westward as a ridge, with a precipitous bluff about 40 feet high, facing north. The upper half or two-thirds of the bluff is Animikie quartzyte and ore, dipping 70° S., and the lower portion is Keewatin(?) greenstone like that north of Akeley lake (the granulitic gabbro, W. S. B.) The contact between the two is fine. The Animikie is but very slightly modified by the igneous rock beneath it. But at other places to the east the Animikie is greatly metamorphosed, so that the line of contact is not discernible. The greenstone near the contact is a little finer grained and less massive than it is two feet below; but no other change is apparent in it. 456 (H), 456A (H), 456B (H), 456C (H), are specimens of this greenstone, taken in order receding from the line of contact. 456D (H) is greenstone from a point 150 paces further west, and 455A (H) is the Animikie above it.

In describing the petrographic features of the rocks it will be best to begin with 456C (H) and pass from this, the most nearly normal phase of the underlying greenstone, to the more special phases occurring nearer the contact and ending with 455A (H), the supposed Animikie above it.

456C (H) consists of coarse grains of gabbroitic plagioclase filled with dust inclusions and tiny crystals of apatite, and large plates and small grains of pyroxene, besides magnetite and biotite. The pyroxene is augite and hypersthene, the former of which not only occurs in the broad plates and large irregular grains characteristic of gabbro, but also in small rounded grains surrounding these, and stretching as aggregates far out between the plagioclases. The hypersthene is found only in the rounded grains. The large grains of augite are much altered, the most prominent alteration products being tiny flakes of a strongly pleochroic reddish-brown biotite, some green hornblende and irregular masses of magnetite. Besides the biotite included within the pyroxene, there are large flakes of the same mineral between the augite and the plagioclase, and others between adjacent feldspar grains. Since the larger flakes are exactly like the smaller ones in every respect but

size, and since the latter are undoubtedly secondary, it is inferred that the larger ones are also secondary, and that their great abundance in the neighborhood of the plagioclase is due to a reaction between this mineral and the augite.

There are other interesting features connected with this slide, but enough has been said to indicate that the rock from which it was made is a true gabbro, in which the beginning of a granulitization of the pyroxene may be detected.

456B (H) differs from 456C (H), mainly in that the plagioclase is more frequently in lath-shaped individuals, and the pyroxene is more completely granulated. Magnetite and biotite are less abundant than in 456C (H), and hypersthene may be more abundant. The rock approaches more nearly the granulitic gabbros than the normal phases of this rock.

456A (H) is a very fine-grained granulitic rock, containing a very large quantity of biotite and magnetite. Occasionally the feldspars have long, narrow cross sections, but in this respect only does the rock resemble diabase. Most of the plagioclase as well as all of the pyroxene is in rounded grains. The magnetite is in irregular grains and in little crystals, and the biotite is in small flakes that are about as broad as they are long. The features are those of a fine-grained eruptive with gabbro characteristics.

456 (H), which, according to the descriptions in the 17th Report, is a specimen taken from the immediate contact of the gabbro' with the overlying beds, is a granulitic gabbro, in which is a vein of very coarse pyroxene. The granulitic portion of the rock is not very different from 456B (H). It is an aggregate of small grains of pyroxene, and of pellucid plagioclase, together with small plates of brown biotite, all including many smaller grains of magnetite, and all arranged in a somewhat parallel manner, that is not the result of pressure. Through this passes a vein of irregularly interlocking, coarse grains of pyroxene, both augite and diallage, and greenish-brown hornblende, scattered through which are a few plates of biotite and grains of plagioclase and magnetite. Along the edges of the vein the amounts of green hornblende, of biotite, and of magnetite increase, and the structure gradually becomes granulitic.

These four specimens are thus seen to belong with the gabbro. The granulitic variety can be traced back into a rock that shows but traces of granulitization, so that there can be but little doubt that the former are, as has been repeatedly

stated, but special phases of the latter. The greenstones underlying the supposed Animikie rocks in this place are then not Keewatin, but they are identical in every respect with the overlying rock, which is certainly not Keewatin.

455A (H). The section of this rock, which is a sample of the supposed Animikie above the greenstone, consists of two very distinct portions. The major part is composed of thickly crowded plates of hypersthene, filled with magnetite and including an occasional grain of quartz. The minor portion is like the crystallized quartzytes 452 (H) and 454 (H), though the quartz grains are perhaps a little more rounded than in these two cases. They include magnetite and rounded grains of hypersthene and numerous large liquid cavities, and are often separated from each other by thin seams of limonite. Between the two areas mentioned is a sort of transition zone in which the quartz-grains and hypersthene are intermingled in about equal proportions with the latter between the grains of the former.

The quartzitic portion of this rock is either a vein in it, or it is but a very acid phase of the granulitic gabbro. In the hand specimen the quartzitic band is but a fraction of an inch in width. In either case the rock loses its importance as a means for determining the age of the gabbro. It is certainly not part of a clastic bed, but it is a portion of the gabbro.

458 (H). (17th Ann. Report, p. 110.) North of the bluff from which 456 (H), etc., were taken, is a still higher ridge in which the rock appears to be slightly different from that in the southern ridge. This rock, under the microscope, is found to be a very fine-grained granulitic aggregate of colorless augite and plagioclase, with a little mica and magnetite and large decomposed areas of what were perhaps originally idiomorphic grains of augite. At present these larger areas consist largely of magnetite dust and green hornblende.

DISCUSSION.

It will not be necessary to discuss the bearing of the nature of the rocks described in the 17th Report upon the geology of the Akeley lake region at as great length as was done in the case of those mentioned in the 16th Report. It will be sufficient to call attention to the fact that the investigation of the former rocks substantiates the conclusions deduced from the study of those whose locations are given in the latter report.

All the beds that were supposed to be Animikie are discovered to be quite unlike any beds that are known to belong to this formation. They all dip at higher angles than do the Animikie rocks, and at the same angle as do some beds that are undoubtedly a part of the great gabbro flow. Moreover, most of the supposed Animikie layers are not fragmental. They are granulitic gabbros that may be traced step by step into a true gabbro, which has all the characteristics of the great gabbro of Minnesota, and which is entirely different from the thin beds of so-called gabbro that are interleaved with the Animikie. The quartzytes among these layers are not fragmental quartzytes, and hence can not be correlated with true fragmental quartzytes as far removed from them as those of Pokegama falls or the falls of Prairie river.* The writer would place them and their contained ores with the gabbro group† of Prof. Winchell. Even should the quartz layers interstratified with the granulitic gabbros be regarded as recrystallized fragmental beds, they would not have the same important significance as would be the case were they truly interstratified fragmentals, for they would owe their present condition to the action upon them of a later eruptive—the gabbro—and thus they could not be used to determine the age of this latter.

SUMMARY.

The three important results reached largely by the microscopic study of the rocks from the neighborhood of Akeley lake, are these:

1. Most of the rocks designated as Pewabic quartzyte in the neighborhood of Akeley lake are not quartzytes, but they are granulitic phases of gabbro. The remainder are crystallized aggregates of quartz. None of them are sedimentary rocks, and consequently none can serve to determine the age of the ore associated with them, or of the gabbro in which they occur.

2. On the other hand, the granulitic gabbros may be traced into true granitic gabbros, and into quartzose phases of granulitic varieties. Hence, the granulitic beds and their associated ores, are of the same age as the gabbro, whose structural relations to the younger and older formations must be appealed to in order to settle the question of age.

* Cf. The Iron Ores of Minnesota: Bull. 6, Minn. Geol. Survey, p. 119.

† Iron Ores of Minnesota, p. 123.

3. Since so much of the "Pewabic quartzyte" is not quartzyte in any sense of the word, and since different beds that have been given this name are not all certainly of the same age*, it is evident that great care must be taken in the use of the "Pewabic quartzyte" for correlation purposes. Several different rocks have been included under this one title, hence, the "Pewabic quartzyte," as defined, cannot be relied upon as marking a definite horizon in the succession of the geological formations in northeastern Minnesota.†

APPENDIX.

Since the above was written, the attention of the writer has been called to the fact that the first and second of the above conclusions are practically identical with those reached by the Lake Superior Division of the United States Geological Survey several years ago. In 1883 and 1884 Mr. W. M. Chauvenet examined in the field the Akeley lake district and that to the westward. Thin sections of his material were examined by Prof. C. R. Van Hise early in 1885. With his field notes as a basis, and the microscopical results of Prof. Van Hise, he submitted a report to Prof. Irving from which the following abstracts are condensed:

Near Little Saganaga lake "An outcrop of heavy magnetitic iron ore rises in a smooth shoulder between walls of a distinctly bedded rock having the appearance of a quartzyte, but which proves under the microscope to be an olivine gabbro with quartz replacement. * * * The silicified gabbro shows distinct banding, stained with iron oxide along the contact of the layers. * * * The bed of magnetic ore occurs, therefore, in the gabbro formation."

The Akeley lake section is fully described. "Along the ridge on the north shore of Akeley lake a number of trenches were opened, which exposed a magnetic ore here occurring in the gabbro. The occurrence is quite similar to that described at Little Saganaga."

*Some are Animikie as determined by Prof. Winchell, while others are of the same age as the gabbro, which is regarded by the Minnesota geologists as Animikie, only because of the supposed interstratification with it of the granulitic gabbros. which were thought to be Animikie quartzyte.

†It is possible that by including under the Pewabic quartzyte only such rocks as are undoubtedly fragmental, as the quartzyte east of Gunflint lake and those along the south side of the Mesabi Range, a constant horizon may be established, which will be of great service in determining the ages of overlying and underlying beds. These rocks, however, cannot be correlated with the granulitic gabbros of the Akeley lake region nor their ores with the ores in the latter. It is this point upon which emphasis is especially placed in the above article.

Then follow details of the alternations of ordinary gabbro and what appears to be bedded quartzyte, after which it is said: "The quartzytes of the above layers all appear to be merely the result of a substitution of quartz and magnetite for the minerals of a gabbro, in some cases for an olivine gabbro. * * * The silicified gabbro on Akeley lake, with seams of magnetite, have been traced southwest through Sections 25, 35, 34, T. 65 N., R. 5 W., to Mitchigamme lake."

Finally the following conclusion is drawn: "It is evident from a study of the rocks at Akeley lake that the iron ore here lies wholly in the gabbro formation, much silicified and altered, and not in the Animikie."

Mr. W. N. Merriam, in 1886, made farther observations on the silicified gabbro belt at lake Gobbemichigomog and vicinity. The sections obtained from the material collected by Mr. Merriam were examined by Prof. Van Hise with the same results as those reached in the case of the Akeley lake rocks.

It thus appears that the Akeley lake silicified gabbro has a considerable east and west extent along the north contact of the gabbro, and that the results which have been reached from a study of the specimens collected by the Minnesota Survey are in accordance with those made by others in an independent study of which the writer was wholly ignorant until his paper was entirely written.

Colby University, Jan. 11, 1892.

NOTE.—The second foot note on the bottom of p. 209, expressing the main point of difference between the conclusions of Prof. Bailey and the reports of the Minnesota survey, is the only one to which here it is appropriate to call attention to. The minor variations in lithologic distinctions, when not due to insufficiency of the supply of material in Prof. Bailey's hands, can all be accounted for and are of but little purport in considering the general succession and structural relations of the formations. It is probable that when Prof. Bailey has seen the structural facts in the field he will modify his conclusions respecting the continuity of the Pewabic quartzyte from the Akeley lake region toward the southwest, and even to Pokegama falls.

There is, as the Minnesota reports have fully explained, a wonderful variety of lithology in the lower part of the Animikie by the agency of cotemporary eruptive action. The "non-fragmental" silica is a chemical precipitate in the early Animikie ocean. At distant points it is pure silica, in rolled grains. At points near the eruptive centers, as at Akeley lake, it has not only not acquired the rounded "fragmental conditions" but it has been crystrilized *in situ* by the heated eruptives, and has been mingled with tufaceous, eruptive fragmental elements. When this mixture is recrystallized it has a remote resemblance to an eruptive rock. But it is of oceanic structure, outwardly and internally, and cannot be affiliated correctly with the true eruptive gabbro.

Of course the intent of Prof. Bailey's paper is to establish the idea of Prof. Irving that the gabbro flood is later than the Animikie rather than near the bottom of it where the Minnesota geologists have placed it, but its purport confirms the Minnesota geologists in their conclusions. N. H. W.

NEW LOWER SILURIAN LAMELLIBRANCHIATA, CHIEFLY FROM MINNESOTA ROCKS.

BY E. O. ULRICH.

In the following pages I endeavor to give full descriptions and, it is hoped, sufficient illustrations of the principal and generally the more striking of the new Minnesota forms of this class that have been brought to my notice since 1885. Much of the material now described I owe to the disinterested kindness of Prof. C. W. Hall, of the State University, and to the unfailing friendship of my co-laborer, Mr. W. H. Scofield, of Cannon Falls. The last sent me every shell and cast of the interior contained in his extensive private cabinet. Many were in a good state of preservation, several belonged to species that I had not before seen (among them the remarkable shell from which I was enabled to work out the characters of the new genus *Plethocardia*), and all proved of material aid to me in determining the essential characters, variations, and limits of the species studied. The value of such aid may be better appreciated when I state that the Minnesota Trenton Lamellibranchiata are no exception to a rule that seems to prevail nearly every where in these rocks, namely, that in most cases the individuals of the species are anything but abundant. Yet, a few forms have been found in considerable numbers, and my observation would indicate that the majority of these shells are more or less gregarious in their habits, so that the number of known specimens of a species may at any time be greatly augmented.

In the Minnesota Lower Silurian rocks, excluding the beds beneath the top of the St. Peter's sandstone, the Lamellibranchiata are confined very largely to six horizons. The first of these is in the upper part of the Trenton limestone in which the fossil itself is almost invariably dissolved away so as to leave good moulds of both the exterior and interior in the matrix. This method of preservation is most favorable, since with the aid of gutta percha the judicious collector may study the most important of the original characters of the shells with comparative ease. Individuals of *Cypricardites rotundus* Hall, are abund-

ant, while another form of the genus near *C. ventricosus* Hall, and *Modiolopsis plana*, of the same author, are not uncommon. The types of *Cypricardites sardesoni* and *C. obtusifrons*, of this paper, are from the same bed, as are several other forms not yet specifically determined.

The second horizon is in the middle third or "Rhinidictya beds" of the Trenton shales. It has afforded *Modiolopsis similis*, *Orthodesma minnesotense*, *Technophorus extenuatus*, *Tellinomya nitida*, *Cypricardites cingulatus*, *C. glabellus*, *C. obtusifrons?*, *Whitella compressa*, and *W. concentrica*, all described by the author. Several other species are represented in my collections by specimens too illy preserved to admit of a satisfactory determination of their affinities.

The third horizon is in a bed that I place near the top of the upper third of the Trenton shales. It is exposed at a locality about six miles south of Cannon Falls, Minn., where it is overlaid by the Galena shales. It is the most interesting horizon for these fossils known to me in the state. Perhaps it is a local deposit, at any rate, none of the Lamellibranchiata described by me from this locality are as yet known in the same position from other points. An incomplete list of the species is as follows: *Tellinomya compressa*, *T. levata* (Hall), *T. planodorsata*, *T. pulchella* (Hall), *Lyrodesma poststriatum* (Emmons), *Modiolopsis concava*, *M. faba?* (Emmons), *Matheria rugosa*, *Cypricardites tenellus*, *C. haynianus?* (Safford), *Whitella scofieldi*, and *Plethocardia umbonata*. All of these species are preserved with the shell, from which the matrix can be cleaned with unusual ease.

In the fourth horizon, a bed of light colored shales underlying the Galena limestone, known to the survey as the Galena shales, all the shells of this class are preserved as casts of the interior. These are sometimes highly satisfactory, yet too often the opposite is true. Many of the specimens from this horizon therefore remain unclassified, and until better material becomes available it will not be possible to give a full list of the species. At least two, and very likely three species of *Cypricardites*, one of them probably *C. haynianus* (Safford), can be made out, besides *Tellinomya levata* (Hall), *T. planodorsata*, *Modiolopsis subelliptica*, *Whitella truncata*, and *Plethocardia suberecta*. There is also an elongate *Tellinomya* near *T. nasuta* Hall, a *Modiolopsis* near *mytiloides* Hall, and enough of other distinguishable forms to bring the total number to fifteen or more.

The fifth horizon is a layer a few feet thick at the base of the Galena limestone that I have named the "Platystrophia beds"

in an unpublished section of the Lower Silurian rocks of Minnesota. From this bed I have seen *Cypricardites tenellus*, *C. nanus?*, *Tellinomya astartiformis* (Salter), *T. intermedia*, *Cleidophorus consuetus*, and several undetermined forms.

The sixth horizon occurs in the Hudson river group at Spring Valley and other points in the southern part of the state. This formation is very thin in Minnesota, and the part represented is equivalent to the upper beds of the group as developed in Ohio and Indiana. Fossils are exceedingly plentiful in some of the layers, but consist chiefly of Brachiopoda. As a rule the Lamellibranchiata have suffered through compression, but a good proportion are in an excellent state of preservation. Among them I have recognized *Ambonychia casei* Meek and Worthen, *Whitella obliqua*, *Lyrodesma major* (described originally by me as *Cleidophorus major*), *Tellinomya recurva*, and *T. similis*, all species occurring also in Ohio. The *Cuneamya sulcodorsata* is, so far as is now known, restricted to this locality. Among the undetermined forms there is a *Modiolopsis* near *pholadiformis* (Hall), another near *M. concentrica* (Hall and Whitfield), one or two species of *Orthodesma*, and a *Tellinomya* near *iphigenia* of Billings.

Respecting the classification of Silurian Lamellibranchiata, it may be well to state that with the progress of our studies we have now arrived at a point where we can appreciate the heterogeneous character of the numerous forms grouped under the generic names *Modiolopsis*, and *Cypricardites*, and in a less degree *Pterinea*, *Ambonychia*, *Tellinomya*, *Cleidophorus*, and *Orthodesma*. I realize fully the inadequacy of the present grouping of the species, yet follow in the same tracks because I fail to see any remedy giving both rapid and permanent relief. Now and then a sharply distinguishable, because essentially Silurian, generic type may be encountered, but many others are indicated which it would be unwise to separate before being closely compared with the wealth of Devonian and Carboniferous forms now known. But that involved more time and labor than I found myself able to devote to the subject, and rather than increase the difficulties of revision, which must be undertaken sooner or later, I have, perhaps unwisely, allowed many species that were determined over ten years ago to be new to science, to lie unpublished in my cabinet. After fully considering the matter, it now appears to me that an incomplete knowledge of our fossil Lamellibranchiata is better than none at all, since the necessity for work in the branch will become all the more evident to students. It was therefore largely in the hope of entic-

ing other energies to the field that I began a series of publications on the subject in the American Geologist. The first of these appeared in the May number, the second in the September, and the third in the December number of that journal, during 1890. It was my intention to continue the papers through the two volumes for 1891, but illness prevented. Among the contemplated papers, one or more which I hope to publish during the present year, is one on species of *Tellinomya* and *Lyrodesma*, a second on *Cleidophorus*, *Cycloconcha*, and *Matheria*, a third on *Orthodesma* and related genera, a fourth on *Cuneamya*, and a fifth on *Ambonychia* and *Pterinea*. When these are published, and the results added to the present paper and the previous publications by Hall, Miller, Meek, and others, the Lower Silurian Lamellibranchiata will have arrived at a promising stage for good classificatory or monographical treatment. Whether or not I shall extend my work on them beyond that stage depends upon circumstances and the success of my endeavors to induce some one of our young paleontologists to take up the group as his specialty.

Two disputed points of nomenclature came up during the preparation of the present paper. The first pertains to the claims for recognition of *Ctenodonta*, Salter, as opposed to *Tellinomya*, of Hall. The latter name has priority, but Hall's original description is so faulty that no blame can attach to Salter for failing to recognize the genus. *Ctenodonta*, on the other hand, was established in a manner so satisfactory that no marked improvement on his diagnosis has since been attempted. Salter's name was adopted by Billings and Safford in this country, and it is now quite generally used in Europe. Hall's name however is used by most American authors. My own views on the points at issue are undecided, and I wish it to be understood that the adoption of *Tellinomya* in the following pages is not to be considered as final, but rather as provisional and in deference to the views of friends and the claims of the venerable author of the name.

The second point, relating to *Cypricardites* of Conrad and *Cyrtodonta* of Billings, brings up questions equally difficult to decide. I shall not here enter upon a discussion of the claims so ably upheld by Hall on the one side, and Billings on the other, and my adoption of *Cypricardites* is to be considered as no more final than in the case of *Tellinomya versus Ctenodonta.*

The thirty two cuts which illustrate the species described in this paper have been reproduced from my own drawings. In

every case the figures have been drawn with great care, and may be relied upon as representing the characters of the species so far as they are known to me.

In describing the rostral portion of the shells it will be noticed that I have, contrary to common usage, often drawn a slight distinction between the terms *beaks* and *umbones.* To meet the want of some term to indicate that portion of the beak which is visible in a side view, I call it the *umbone,* while the application of the term *beak* was restricted to the incurved extremity that in most cases is visible only in a dorsal or anterior view.

TELLINOMYA NITIDA, n. sp.

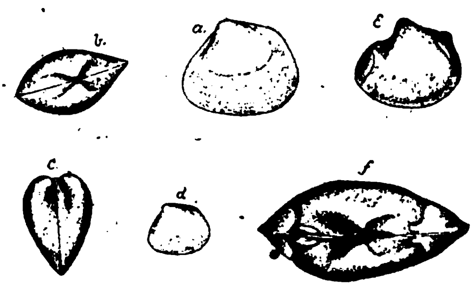

FIG. 1. *Tellinomya nitida.* n. sp. *a, b* and *c.* left side, cardinal, and posterior views x2, of a small specimen retaining the shell; *d,* natural size view of same; *e,* left side of a large and very perfect cast of the interior, nat. size; *f,* cardinal view of same, x2 to show the muscular scars.

Shell small, thin, moderately ventricose, subtriangular, the antero-cardinal region somewhat alated; umbones full, beaks closely incurved. Posterior extremity oblique, rather abruptly truncated, flattened, nearly straight, pinched and projecting slightly beyond the convex part of the shell in the upper half, and narrowly rounded below. Ventral margin gently convex, usually curving rather sharply upward at the ends. Anterior end wide, rounded and most prominent in the lower half, straightened above, the junction with the hinge-line subangular. Surface, excepting a few indistinct lines of growth, smooth.

Casts of the interior have strongly projecting beaks. The internal characters of the shell, so far as they can be made out from these casts, are as follows: Hinge line very slightly arcuate, with eight or nine strong teeth behind the beaks, and an undetermined number of smaller ones in front. Anterior

and posterior muscular impressions subequal, distinct, the posterior ones drawn out along the hinge margins. Above the anterior pair there is another much smaller elongated pair, lying close to the hinge. These features are all shown in fig. *f* of the above cut.

This species evidently belongs to the group of species of which *T. levata* Hall is a type, but its posterior end is shorter and more abruptly truncated, agreeing in that respect more closely with *T. abrupta* (*Ctenodonta abrupta* Billings). The latter however is a more ventricose and longer shell, and not as wide anteriorly.

Formation and locality:—Good specimens of this species with the shell are exceedingly rare, but casts of the interior are common in the middle third of the Trenton shales, of Minneapolis, Fountain and other localities in the state of Minnesota.

TELLINOMYA COMPRESSA, n. sp.

FIG. 2. *Tellinomya compressa*, n. sp. *a*, right valve of this species; *b*, posterior view of same; *c*, same, x2, showing the extremely fine concentric lines of the surface. These are preserved at the posterior end of the shell only.

Shell small, erect, the height greater than the length, subtriangular, compressed, thin; beaks small, almost acuminate, moderately incurved; umbones rather flat, the convex part of the shell terminating somewhat abruptly along the anterior and posterior cardinal margins. In the outline, these two margins, meeting at the beaks, form an angle of about 85 degrees, with the anterior gently convex and the posterior correspondingly concave. Aside from this difference in the curvature of the upper parts the ends are subequal, and round uniformly into the strongly convex ventral edge. Surface with faint lines of growth, and exceedingly fine, crowded, concentric striæ, six to eight in one mm.

Hinge line bent at a right angle, with about twenty teeth, the central ones very small, those on each side larger and bent. Muscular impressions not observed.

This species forms one extreme and *T. pectunculoides* Hall, the other, of a group of at least ten species of which *T. astartiformis* Salter, may be taken as the type. They are all much shorter than the species of the typical section of the genus.

Compared with related species *T. alta* Hall, is more erect, more ventricose, with the ventral margin less convex, and a thicker shell. *T. astartiformis* is near but differs in being more ventricose, more coarsely striated, and in having more obtuse beaks. Salter's species, excepting that it is more ventricose than either, is in all other respects very nearly intermediate between *T. compressa* and *T. intermedia.*

Formation and locality:—In the upper third of the Trenton shales, six miles south of Cannon Falls, Minnesota. It is here associated with *T. levata?* Hall, *T. pulchella* Hall, *Lyrodesma postrtriatum* Emmons, *Modiolopsis concava*, n. sp. and a fossil very much like *Salterella billingsi* Safford.

TELLINOMYA PLANODORSATA, n. sp.

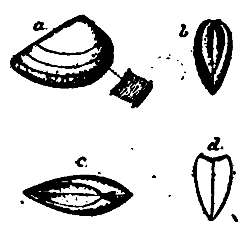

FIG. 3. *Tellinomya planodorsata*, n. sp., *a*, *b*, and *c*, left side, posterior, and dorsal views of the nearly perfect type specimen of this species, nat. size; *d*. sectional view of same, with the posterior dorsal side at the top of the figure.

Shell small, depressed convex, subtriangular or trapezoidal, the width and length respectively as ten is to fourteen; beaks small, incurved, scarcely projecting above the hinge, and situated about one third of the entire length from the anterior extremity. Posterior end long, subtriangular in outline, with the extremity subacute, and the dorsal side almost straight (faintly convex) from the beaks backward; ventral margin broadly rounded, anterior edge more strongly convex. Postero-cardinal side thick, with a large, sharply defined, and slightly concave lunette, reaching from the beaks to near the posterior extremity of the shell. Surface gently convex, scarcely sloping toward the lunette, marked with exceedingly fine striæ and a few stronger lines of growth.

Interior unknown, unless a cast of the interior from the overlying Galena shales belongs to this species. This cast which was formed by a shell of scarcely three fifths the length of the type specimen, agrees in most respects, only the beaks project considerably above the hinge line, causing the posterior cardinal line to be concave instead of straight or slightly convex. Still, we must remember that it is the inner or lower

side of the hinge plate that is represented in the internal cast, and as this is always thicker in these shells than the shell substance at the head of the beaks, it is to be expected that the latter would be more prominent in the casts than in the shell itself. The cast in question is considerably like those of *T. levata* Hall, differing mainly in being a little longer, less ventricose, with the back flatter, and in having the muscular scars much less distinct. Indeed, the latter are so faint that their shapes cannot be made out with certainty—a condition, again, to be expected in a species that evidently depended chiefly upon the large size and strength of the external ligament to keep its valves in position.

Taking the shell itself, I know of no species with which it might be confounded.

Formation and locality:—Same as the preceding.

TELLINOMYA INTERMEDIA, n. sp.

FIG. 4. *Tellinomya intermedia*, n. sp. *a*, and *b*, right and posterior views of an average example of this species, nat. size; *c*, cast of the interior of a left valve, nat. size, showing muscular scars, impressions of hinge teeth, and obtusely ridged character of the antero-cardinal region.

Shell thin, of medium size, moderately ventricose, rather erect, the height a little greater than the length. Outline subtriangular, at the beaks, which are obtusely acuminate and incurved, forming very nearly a right angle; anterior cardinal margin very gently convex, posterior cardinal edge correspondingly concave, ventral margin together with the curve into the ends forming a semicircle. Ends sub-equal, the posterior sometimes a little the longest (see fig. 4 *c*.). Umbones full, the remainder of the surface sloping uniformly to the free margins. An obscure sulcus may be detected near the anterior margin, and along the dorsal part of this end the surface descends abruptly to the hinge plane. Surface with strong, closely arranged, thread-like, concentric lines, about twelve in 5 mm. At intervals of about two or three mm. generally a fold stronger than the rest.

Casts of the interior exhibit a faint ridge and sulcus in the anterior end, two sharply defined muscular scars and pallial line in each valve, and above the posterior pair a much smaller

pair of scars situated close to the hinge. Hinge plate rather narrow, the teeth numerous, over thirty, as usual very small centrally, growing larger gradually toward the ends of the hinge.

This species is associated with and closely related to *T. astartiformis*, described by Salter from the Black River and Trenton limestones of Canada, but is a less ventricose shell, with coarser striæ, and more rounded ends and ventral margin. *T. compressa*, occupying a lower horizon, is more compressed, higher, has sharper beaks, and much finer striæ. Both *T. subrotunda* and *T.* (?) *hamburgensis* Walcott (Mon. U. S. Geol. Sur., vol. 8, p. 76) have a more rounded outline.

A very similar but smaller and clearly distinct species, differing chiefly in the crenulation of the hinge, occurs in the Utica horizon of the Cincinnati group, at Covington, Kentucky.

Formation and locality:—Not uncommon at the Platystrophia horizon at the base of the Galena limestones, near Fountain, Minnesota.

TELLINOMYA SUBROTUNDA, n. sp.

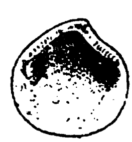

FIG. 5. *Tellinomya subrotunda*, n. sp. Two views, external and internal, of a well preserved right valve, nat. size.

Shell of medium size, comparatively thick, compressed, nearly circular in outline, with the beaks small, prominent, rather acuminate, curving inward and posteriorly. Posterior dorsal line straight except just beneath the beaks where it is concave. Anterior dorsal margin gently convex, rounding gradually into the general outline. Umbones small, the surface almost uniformly depressed-convex. At intervals of from two to three mm., the surface presents strong, lamellose lines of growth, and between these much finer concentric lines, about six in two mm.

Interior with subequal, ovate, moderately impressed, anterior and posterior muscular scars. Hinge plate strong, bent

at a little more than a right angle, with numerous (about thirty-five) small teeth, as usual strongest near the extremities of the hinge.

This species is more rounded and less ventricose than *T. intermedia*, is more rounded and evenly convex than *T. compressa*, and has more prominent beaks and more abruptly bent hinge than *T. pectunculoides* Hall. A species intermediate in character between the last and the present form, and the nearest relative of *T. subrotunda* known to me, occurs in the upper beds of the Cincinnati group at several localities in Ohio.

Formation and locality:—Base of the Trenton limestones, Mercer county, Kentucky. It is possible that certain illy preserved casts of the interior, from the upper part of the Trenton shales, near Cannon Falls, Minnesota, may belong to this species.

TELLINOMYA SIMILIS, n. sp.

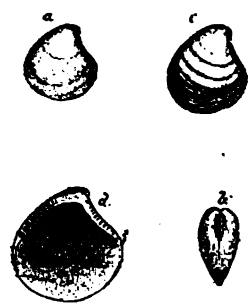

FIG. 6. *Tellinomya similis*, n. sp. *a* and *b*, left and posterior views of a rather small shell; *c*, left side of another specimen; *d*, interior of a large right valve. All the figures are of the natural size.

Shell small to medium size, moderately ventricose, subtriangular, the length and height respectively as five is to six. Umbones full, rounded, the rostral portion strongly recurved, with the beaks small, and projecting slightly above the hinge. Antero-dorsal edge convex, thick, flattened, but not sharply defined. Postero-dorsal edge rather strongly concave, impressed so as to form an illy defined, imperfect lunette. Anterior side almost uniformly convex, curving neatly into the well rounded ventral margin. Posterior side rather narrowly rounded and slightly produced in the lower half. Surface almost uniformly convex, highest a little above the center, generally with a few well-marked varices of growth, and with finer concentric lines in the lower part. Hinge plate of moderate strength, with numerous small teeth (thirty-five to forty-two), in the largest example seen with about twenty-seven anterior and fifteen posterior to the beak. Posterior teeth the largest, bent. Muscular scars faintly impressed.

The shape of this species is exceedingly like that of *T. astartiformis* Salter, of the Black River and Trenton limestones, but it is not so ventricose. If the hinge of that species is correctly represented in Salter's figures, the form under consideration must be regarded as specifically distinct, since it has smaller, less bent and more numerous teeth. According to Salter the teeth of *T. astartiformis* are largest on the anterior side, while in *T. similis* the opposite is the case.

It is also very much like its associate, *T. recurva*, but is distinguished by being a little higher, more uniformly rounded on the anterior side, and without the anterior sulcus. More important differences are the greater tumidity of the umbones, less prominent beaks, scarcely defined posterior lunette, and less strong hinge plate. Casts of the interior are separated chiefly by the greater thickness of the rostral portion. They are also nearly always of smaller size than those of *T. recurva*.

Formation and locality:—Upper beds of the Hudson River group, Spring Valley, Minnesota, and Blanchester, Ohio.

TELLINOMYA RECURVA, n. sp.

Fig. 7, *Tellinomya recurva*, n. sp. *a* and *b*, external and internal views of a left valve, nat. size; *c*, hinge of same, x2; *d*, posterior view of same; *e*, another left valve, nat. size, of somewhat different shape. Specimens from Spring Valley, Minn.

Shell small or of medium size, not thick, rather compressed, subtriangular, the length and height almost equal. Rostral portion strongly recurved, umbones small, depressed, beaks very prominent, posterior to the center of the shell. Dorsal slopes flattened, sharply defined, with the ridges projecting beyond or overhanging the edge of the hinge plate. This is true especially of the posterior side, where they form an elongated lunette. Anterior dorsal margin more strongly convex than in any other species known; posterior dorsal margin correspondingly concave. Outline, with the anterior side rather sharply rounded in the lower half, the ventral margin sloping

backward and most prominent a little behind the center, then curving upward to meet the concave posterior side at a point very nearly opposite the middle of the height of the shell. Posterior end rather narrowly rounded, most prominent just beneath the center. Surface with several strong growth lines, and between them fine concentric striæ, about ten in three mm. An obscure sulcus extends from the beak along the anterior margin to the antero-ventral region. Hinge plate very strong, bent at a right angle, the posterior half straight, with at least twenty small teeth, decreasing in size gradually toward the beak; anterior half gently convex, with about thirty teeth. Considering the unusual strength of the hinge plate, the teeth are very small. Anterior and posterior muscular scars large, moderately impressed.

Compared with other species the nearest appear to be *T. astartiformis* Salter, and *T. compressa*, and *T. similis* of the present paper. From the first it is distinguished by being less ventricose, in the flattening of the dorsal edges, and in the greater number and smaller size of the hinge-teeth. The second is more compressed, and has more erect beaks, finer surface striæ, and fewer hinge teeth. The third is without the anterior sulcus, has no sharply defined posterior lunette, is higher, generally of smaller size, and has the umbones more tumid, with the point of greatest convexity above the center.

Formation and locality:—Upper beds of the Hudson River group, Spring Valley, Minnesota. It is here associated with *T. similis*, *T.* near *iphigenia* Billings, *Lyrodesma major* Ulrich, and an abundance of Brachiopoda. Casts of the interior, apparently referable to this species, occur in equivalent beds at Oxford, Waynesville, and other localities in Ohio.

TECHNOPHOROUS (?) EXTENUATUS, n. sp.

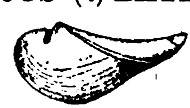

Fig. 8, *Technophorus (?) extenuatus*, n. sp. Left side of the only example, a nearly perfect cast of the interior, seen. nat. size.

Shell small, compressed, elongate, alated and drawn out posteriorly. Beaks small, erect, moderately prominent, situated about one-fourth of the entire length from the anterior extremity. Just in front of the beaks the casts of the interior exhibit a deep though not very long impression. Anterior end broad, rounded, most prominent in the upper third; ventral margin broadly convex and slightly produced a little in front of the middle; behind this point the outline is nearly straight (slightly concave) sloping up toward the narrow (? pointed)

posterior extremity. Cardinal line nearly as long as the entire shell, gently concave behind the beaks. A thin, sharply defined ridge, slightly curved, extends across each valve from the beak to the lower side of the posterior end. Surface gently convex in the anterior half, marked with obscure concentric lines of growth.

Length about 21 mm., greatest height 10 mm., greatest convexity about 3.5 mm.

This is a peculiar shell, and it is with considerable doubt that I refer it to the recently proposed genus *Technophorus*, Miller (North Amer. Geol. and Pal., p. 514, 1890). I do so because in another undoubted species of the genus in my possession the posterior extremity of the hinge is drawn out in a manner similar to what we see in the present shell. The prolongation however is much less extensive in the undescribed species. Both the latter and Miller's type of the genus (*loc. cit.*) have two posterior ridges crossing each valve, and in both again the hinge line is straight.

The Cincinnati species which I called *Nuculites yoldiaformis* (Jour. Cin. Soc. Nat. Hist., vol. 2, p. 24, 1879), is probably a related form.. As it is clearly not a true *Nuculites* and seemingly without any near relations to any established genus, it might be well to erect a new genus for their reception.

Formation and locality:—Rare in the middle third of the Trenton shales at Minneapolis, Minnesota. I am indebted to the liberality of Prof. C. W. Hall, of the State University of Minnesota for the only specimen seen.

CLEIDOPHORUS CONSUETUS, n. sp.

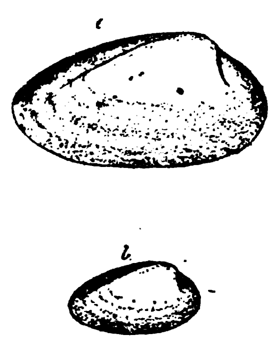

Fig. 9. *Cleidophorus consuetus*, n. sp. *a*, cast of a right valve of this species, x2; *b*, same of the natural size.

Shell above the medium size for the genus, transverse, moderately elongate, ovate, rather strongly convex, the length equaling nearly twice the height. Beaks small, incurved, flat-

tened. Dorsal line convex, sloping downward behind the beaks to the narrowly rounded posterior extremity. Anterior end neatly rounded, wider than the posterior. Ventral margin gently convex in the middle, more strongly and almost equally curved at the ends. An obscure umbonal ridge traceable from the beaks three fourths of the distance to the posterior basal edge. Above it an impressed narrow line, beyond which the surface descends rapidly to the dorsal margin. Casts of the interior with a narrow, slightly curved, clavicular impression just in front of beaks, extending but little more than one third of the distance to the antero-basal margin. Surface of casts with a few obscure growth lines or folds. Point of greatest convexity a little above and behind the center of the shell. In a dorsal view the central half of the outline is very slightly flattened.

Length 17.2 mm., height 9.0 mm., thickness of both valves 5.3 mm.

This shell appears to be related to *C. cuneatus* and *C. elongatus*, described by Hall from the Silurian rocks of Nova Scotia (Can. Nat. and Geol., vol. 5, pp. 148 and 150, 1860). It is however specifically distinct, the shape being different and the posterior sinus situated higher up and very much less defined. *C. planulatus* (Conrad) and *C. ellipticus* Ulrich, also have somewhat different outlines, and have the cardinal slopes less abrupt, the whole surface in those species being more uniformly and less convex.

Formation and locality:—Rare in the Platystrophia horizon at the base of the Galena limestones. It is associated with *Tellinomya intermedia Ulrich.*

MODIOLOPSIS PLANA, Hall.

Modiolopsis planus HALL. 1861. Report Superintendent Geol. Sur. Wis., p. 30. Geol. Wis. vol. I, pp. 38 and 438, fig. 6.

The above cut represents an internal cast of the left valve of a shell that occurs rather rarely in the upper beds of the Trenton limestones at Minneapolis and other localities in the state. There can be no question of the identity of this Minnesota form with the Wisconsin types of the *Modiolopsis plana* Hall. The latter seem to have been smaller, being said to be about

three-fourths of an inch in length, but in all essential respects, our specimens agree sufficiently well with Hall's description and figure.

Among the most important features of the species is the elongate form and duplex character of the strongly impressed anterior muscular scar, the alate character of the postero-cardinal region, the length and straightness of the hinge line, and the wide truncated posterior end. The hinge also seems to have been unusually strong. In most of these respects the species approaches *M. truncata* Hall, of the Cincinnati group, more or less nearly.

These two species, together with several others, stand apart from the typical section of the genus, and should perhaps be separated under another generic name. But the whole genus *Modiolopsis* needs revision, and when this is done it will, I am satisfied, be found necessary to institute several subdivisions.

MODIOLOPSIS SIMILIS, n. sp.

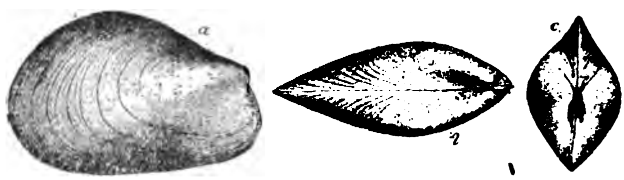

Fig. 11, *Modiolopsis similis*, n. sp. *a*, *b*, and c, right side, dorsal, and anterior views of a well preserved cast of the interior. nat. size.

Shell of medium size, elongate, ovate, widest in the posterior half, contracting to between one half and three fifths of the greatest width at the beaks. Hinge line nearly straight and about half as long as the shell posterior to the beaks. Anterior end small, neatly rounded; ventral margin nearly straight in the middle, curving up at the ends; posterior end broadly rounded, slightly produced in the lower half, sometimes forming an obtusely angular junction with the hinge line. Beaks nearly terminal, rather small, compressed, incurved, projecting moderately above the hinge. Surface moderately convex, most prominent along the posterior umbonal ridge, which is stronger than usual in species of this genus. Cardinal slope concave. A broad and comparatively well defined, mesial depression extends obliquely across the shell from the beak and, expanding, causes the straightening of the ventral margin.

Shell very thin, so that the muscular scars are scarcely visible in the casts. Surface with numerous fine concentric lines, and some stronger varices of growth.

Of all the described species of this genus known to me *M. concentrica* Hall and Whitfield, from the upper beds of the Cincinnati group, seems to be nearest. Excepting that the Minnesota shell is wider posteriorly, the two species agree very nearly in their outlines. In other respects however they are quite different, *M. concentrica* having a thicker shell, with the anterior muscular scar much more distinct, the beaks projecting less, the posterior umbonal ridge and median depression both lesser features, and the surface markings coarser. The outline of an undescribed species, from the base of the Trenton limestone of central Kentucky, agrees even better in its general contour with *M. similis*. But it too seems to be distinct, since in it the umbonal ridge and the mesial sinus are even less distinguishable than in *M. concentrica*.

Because of the exceeding thinness of its shell I would place *M. similis* into the same section of the genus that includes *M. cincinnatiensis* Hall and Whitfield, *M. pulchella* Ulrich, and *M. subtruncata* Ulrich. These are all widely removed from *M. modiolaris* Conrad, the type of the genus, and in some respects are nearer *Orthodesma*, Hall and Whitfield.

Formation and locality:—Rare in the middle third of the Trenton shales, at Minneapolis, Minnesota, where the illustrated specimen was found by Prof. C. W. Hall, of the State University, who kindly gave it to me for description.

MODIOLOPSIS SUBELLIPTICA, n. sp.

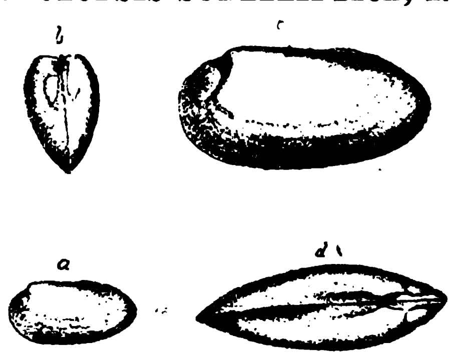

Fig. 12, *Modiolopsis subelliptica*, n. sp. *a*, left side of a cast of the interior, nat. size; *b*, *c*, and *d*, anterior, lateral, and dorsal views of same, x2.

Shell small, elongate-elliptical in outline, the length fully twice as great as the breadth, a little the widest anteriorly, with the dorsal and ventral margins subparallel and both gently

convex, the anterior end semicircular, the posterior more narrowly rounded and slightly produced in the middle. Beaks small, incurved, projecting but little above the hinge, situated about one-fifth of the entire length from the anterior extremity. Umbonal ridge slight, running close to the dorsal margin, causing the central part of the dorsal side of the shell to be somewhat flattened. Sides of valves moderately convex, with point of greatest convexity a little in front of and above the middle.

Casts of the interior show a sharply defined, ovate, anterior muscular scar, which must have been bounded on the inner side by a strong internal ridge, extending downward and curving forward from the hinge, at a point just in front of the beaks, to the lower end of the muscle. The posterior scar and pallial line are not distinguishable in the material at hand. The lower and anterior parts of casts exhibit a few, obscure, broad lines of growth.

This is one of a small group of species that remind one greatly of *Cleidophorus*, Hall, to which genus they might be referred were it not for the distinct impression of the anterior muscular scar. The shape and size of the present species is considerably like that of *Cleidophorus consuetus*, described in this paper, but, aside from other differences, the one relating to the presence of a muscular scar will distinguish them at once. I know of no described species of *Modiolopsis* sufficiently resembling this to necessitate comparisons.

Formation and locality:—Galena shales, near Cannon Falls, Minnesota.

MODIOLOPSIS CONCAVA, n. sp.

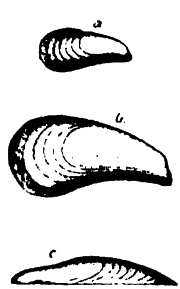

Fig. 13. *Modiolopsis concava*, n. sp. *a*, right valve of the natural size; *b*, and *c*, side and dorsal views of same, x2.

Shell very small, elongate, the greatest width less that half the length, curved, the posterior end much the widest, broadly rounded, the anterior end exceedingly short and narrow, con-

tracted beneath the beaks, which are small, compressed, and project but little above the hinge. Height of posterior third about two and one-half times as great as at the beaks. Dorsal side gently arcuate; anterior two-thirds of ventral margin strongly concave, a fact due in a great measure to the width of the sulcus and the rapid slope of the surface included in it. Umbonal ridge slight, cardinal slope rather strongly convex. In a dorsal view the anterior half of the shell appears compressed, yet the point of greatest thickness is very near the middle of the length.

Surface marked simply with concentric lines of growth. Internal characters not observed.

This peculiar species is another of the number that I am referring to *Modiolopsis* provisionally. I place it here, first, because it seems to be related to some forms of the *M. faba* section of the genus, and, second, because I know of no other established genus that would offer a more fitting placement.

Formation and locality:—Upper third of the Trenton shales, about six miles south of Cannon Falls, Minnesota.

ORTHODESMA MINNESOTENSE, n. sp.

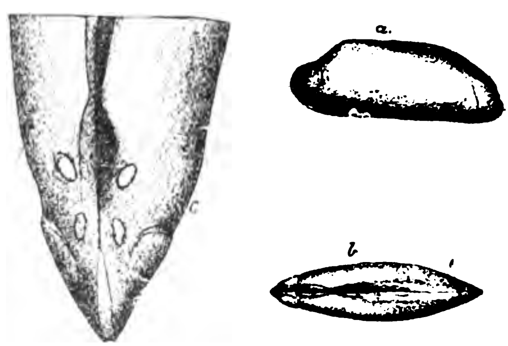

Fig. 14. *Orthodesma minnesotense*, n. sp. *a* and *b*, left side and dorsal views of a cast of the interior; *c*, dorsal view of anterior third enlarged to show the muscular scars, x4.

Shell small, elongate, subrhomboidal, with the dorsal and ventral margins nearly straight and parallel; the length two and one half times the width. Beaks small, incurved, compressed, projecting moderately above the hinge, and situated about one fourth of the entire length from the anterior extremity; posterior umbonal ridge subangular, cardinal slope abrupt, in casts of the interior with a linear impression close to and on each side of the hinge line. Anterior end small, contracted a little in front of the beaks, almost uniformly rounded; posterior

end oblique, sloping upward and forward from the produced and narrowly rounded lower part.

Interior with the anterior pair of muscular scars rather distinctly marked and large; above and between them and the beaks, two other very small pairs of scars are to be seen on the specimen figured above, but the posterior muscles left no appreciable impressions. Surface of casts with a few obscure folds of growth.

This species is related to *O. curvatum* Hall and Whitfield, though more nearly approaching *O. contractum* Hall, in the general outline. It differs from both in having the posterior end narrower, and in wanting the strong wrinkles which occur on the posterior cardinal slopes of those shells.

Formation and locality:—Middle third of the Trenton shales. St. Anthony Park, St Paul, Minnesota.

ORTHODESMA SAFFORDI, n. sp.

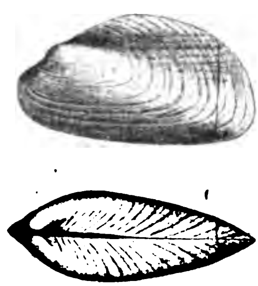

Fig. 15. *Orthodesma saffordi*, n. sp. Two views, side and dorsal, of a rather small specimen of this species, nat. size. The largest specimen seen is at least one-third larger.

Shell of medium size, elongate, trapezoidal, widest posteriorly, the length somewhat less than twice the greatest width; hinge line straight, with a narrow, concave ligamental area, extending about one-half of the entire length from the anterior extremity; ventral margin nearly straight or slightly convex, forming an angle of about 38 degrees with the hinge line. Anterior end narrow, about half as wide as the posterior part of the shell, its length equalling about one-fifth of the entire length, the outline erect above, subangular where it joins the extremity of the hinge, rounding below into the basal line. Posterior end wide, sharply curved and produced below, more gently curved and sloping forward in the middle and upper thirds, meeting the extremity of the hinge line without forming any perceptible angle. Beaks small, incurved, somewhat flattened on the umbones, projecting slightly above the hinge; umbonal ridge

strong, subangular, traceable generally to the postero-basal margin; cardinal slope at first concave, gradually flattening posteriorly; with a distinct, linear sulcus running midway between the umbonal ridge and the dorsal margin, and both above and beneath this, several other, but more obscure, radiating lines may be detected; ventral slope flattened.

Surface of the shell marked strongly with rather irregular and unequal concentric lines of growth. The radiating lines on the cardinal slope have been mentioned.

One of the specimens preserves a considerable part of the hinge. It is, so far as can be seen, perfectly straight both in front and behind the beaks, and without teeth or thickenings. The ligamental area, however, is rather wide and concave. Muscular impressions unknown.

This species is wider posteriorly than any other *Orthodesma* known to me. In the general outline, excepting that the beaks are too far from the anterior extremity, and the hinge too straight, it is more like *Modiolopsis.* But it has the same kind of hinge as *Orthodesma rectum* Hall and Whitfield, the type of the genus.* The depressed line in the cardinal slope is another feature that is frequently met with, especially in the casts of species of *Orthodesma.*

It gives me much pleasure to name this fine species for Prof. Jas. M. Safford, of Nashville, Tennessee, as a slight token of my appreciation of his valuable and long continued labors in American geology.

Formation and locality:—In the lowest member, Safford's "Central limestone," of the Trenton formation, at Murfreesboro, Tennessee. The beds holding this fossil are equivalent to either the Chazy or the lower part of the Birdseye.

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*Hall and Whitfield say, in their generic description (Pal. Ohio, vol. ii, p. 93), that the hinge line is "contracted or bent beneath or anterior to them". *i. e.* the beaks, and this supposed feature they relied upon chiefly in distinguishing their genus from *Orthonota*, Conrad. But this supposed bending or contraction of the hinge line does not exist in *O. rectum* nor in *O. curvatum* or in any other species of *Orthodesma* known to me. The evidence bearing upon the disputed point afforded by my collections is, at any rate in the two species mentioned, unequivocal.

CYPRICARDITES SARDESONI, n. sp.

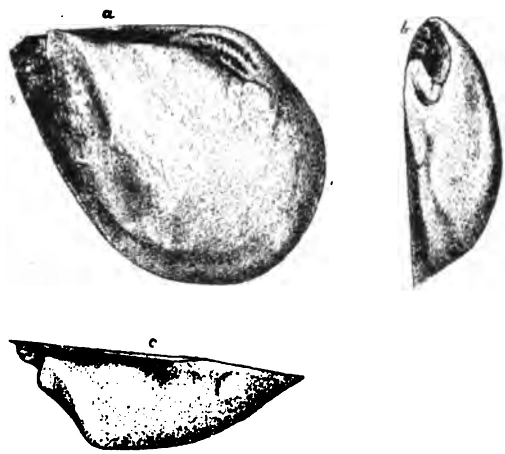

Fig. 16. *Cypricardites sardesoni.* n. sp. *a, b* and *c*, lateral, anterior, and dorsal views of a cast of the interior of a right valve, nat. size.

Shell of the medium size, known only from casts of the interior, and the impression of the hinge and free margins on the limestone matrix. The outline was subrhomboidal, with the cardinal and anterior margins nearly straight, and the two lines forming an angle of about 62 degrees; anterior extremity suba cute or sharply rounded; hinge line equaling nearly three-fourths of the entire length; postero-ventral margin broadly rounded, almost semicircular; above this the posterior outline is somewhat straightened and slopes forward rapidly, meeting with the cardinal line to form an angle of about 135 degrees; the immediate junction however is not perceptibly angular.

In the casts the beaks project strongly, are nearly terminal, pointed, slightly incurved, greatly compressed, and somewhat twisted. A strong sulcus extends from the beaks to the antero-basal part of the cast; this sulcus occupies the larger part of the anterior slope, and from its inner side the umbonal ridge, constituting the highest portion of the surface, rises abruptly. For the reasons mentioned the anterior slope appears flattened and in part concave, while the posterior is almost uniformly convex to the margin. Cardinal slope abrupt, especially near the hinge.

Fig. 17. Interior of left valve of *Cypricardites sardesoni*, n. sp., as shown in gutta-percha impressions.

Gutta-percha impressions, as shown in fig. 17, bring out the internal characters in a very satisfactory manner. They show a wide and faintly striated ligamental area, two lateral and two cardinal teeth, both pairs strong and distinctly crenulated on the sides. The cardinal pair are considerably curved, and the lower one forms the upper boundary of the very sharply impressed anterior muscular scar. On the whole the hinge impresses one as being unusually strong. The posterior muscular scar is large, ovate, double or prolonged below, and but faintly impressed.

I know of no associated species, nor of any now referred to this genus, that is at all likely to be confounded with *C. sardesoni*.

The specific name is given in honor of the discoverer, Mr. F. W. Sardeson, of Minneapolis, Minnesota, an enthusiastic collector and a promising student of paleontology.

CYPRICARDITES OBTUSIFRONS, n. sp.

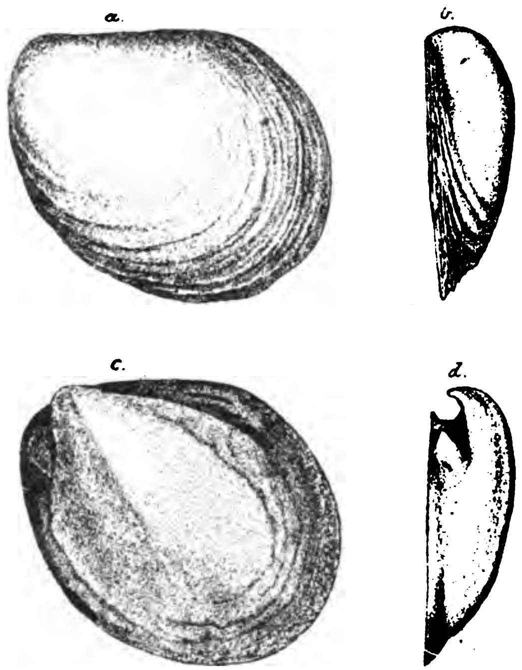

Fig. 18, *Cypricardites obtusifrons*, n. sp. *a*, and *b*, lateral and anterior views of a gutta percha impression of the exterior of a left valve; *c*, and *d*, similar views, of the cast of the interior of same shell; all nat. size.

Shell of medium size, scarcely ventricose, oblique, subovate, widest and broadly rounded posteriorly, with the beaks subterminal, small, projecting very slightly; umbonal region full, but scarcely distinguishable in the general convexity of the surface; anterior end obtuse, forming nearly a right angle with a straight hinge line, the junction between the two rounded; posterior and basal margins semicircular. Surface with the greatest convexity in the antero-dorsal third, the cardinal and anterior slopes more gently convex; surface markings consisting of rather irregular, fine and coarse, sublamellose lines of growth.

Casts of the interior with the beaks large, compressed, strongly, incurved; a moderate umbonal ridge and sulcus crosses the casts from the beaks in a direction nearly parallel with the anterior margin, becoming obsolete before reaching a point near the middle of the basal line. Anterior muscular scar deeply impressed, rather large, partly overhung by the projecting beak. Posterior scar illy defined.

Fig. 19. View of a gutta percha impression taken from a mould of the interior of a left valve of *Cypricardites obtusifrons*, n. sp.

The gutta percha impression illustrated in fig. 19, was prepared from the cast of the interior represented by fig. 18, *c* and *d*. It shows that the hinge plate was strong, nearly flat in the central part, with three strong lateral teeth, and two small anterior cardinal teeth. Just in front and beneath the latter is the large and strongly impressed anterior muscular scar.

In some respects this species is like *C. sardesoni*, which is also associated with it in the limestone, but a comparison of the figures here given of the two species will show so many striking differences that there is really no danger of confusion between them. Some resemblance is also to be noted to species like *C. obtusus* Hall, *C. saffordi* Hall, and *C. haynianus* Safford, but they are all really quite different internally, and in having the umbones more prominent. *C. niota* Hall, occupying a similar position in Wisconsin, is likewise to be compared. It is a more erect shell, and differs in other particulars as well.

Formation and locality:—Collected by Prof. C. W. Hall, of the State University, in the upper beds of the Trenton limestone, at Minneapolis, Minnesota.

CYPRICARDITES GLABELLUS, n. sp.

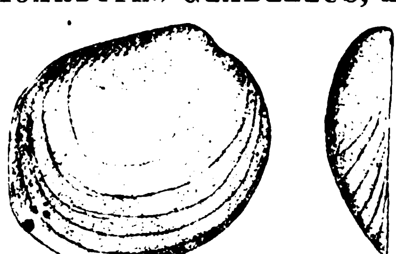

Fig. 20. *Cypricardites, glabellus*, n. sp. Lateral and anterior views of a right valve.

Shell scarcely reaching medium size, broad-ovate or subquadrangular in outline, with the back straight, the posterior margin sloping forward in the upper fifth, straightened and

nearly vertical in the middle, and curving forward below into the broadly rounded ventral margin; anterior side convex, short. Beaks small, the umbonal region full, very slightly prominent, with the line of greatest convexity—not sufficiently defined to be called a ridge—extending obliquely across the valves from the beaks toward the postero-ventral edge; point of greatest convexity very near the center of the shell. Cardinal slope flat, rather abrupt; between this and the undefined umbonal ridge the surface is again slightly flattened; anterior and basal slopes gently convex. Surface nearly smooth, near the margins marked simply with a few lines of growth. Internal characters unknown.

The outline of this species is about intermediate between *C. ventricosus* Hall, and *C. niota* Hall, but the relations between them are, I am satisfied, quite remote. Both those species are at once distinguished by the greater prominence of their umbones.

Formation and locality: —Rare in the middle third of the Trenton shales, at Minneapolis, Minn. A cast of the interior from the "Buff limestone" at Beloit, Wis., now before me, may belong to this species.

CYPRICARDITES CINGULATA, n. sp.

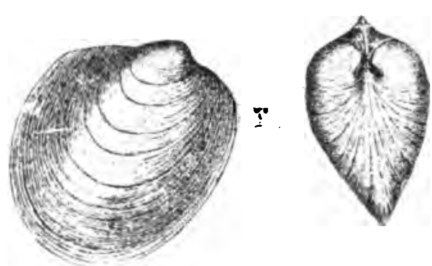

Fig. 21. *Cypricardites cingulata*, n. sp. Lateral and anterior views of a nearly perfect specimen of this species, nat. size.

Shell scarcely reaching the medium size, ventricose, oblique, the outline, excepting a slight prominence at the postero-cardinal edge, regularly ovate, but narrow anteriorly and broadly rounded posteriorly; hinge line rather short posterior to the beaks, slightly convex; beaks of good size, strongly incurved, projecting well above the hinge, situated one fifth of the entire length from the anterior extremity; umbones prominent, full, with an obtuse ridge or line of greatest altitude running from the beaks toward the postero-basal side; anterior and cardinal slopes both slightly concave, the latter descending more abruptly. Point of greatest convexity near the middle of a line

drawn parallel with, and one-third of the height of the shell beneath the hinge. Surface marked with very fine concentric lines, easily abraded, and distant irregular lines or wrinkles of growth. Shell substance thin. Internal characters unknown.

This species seems to be rather closely related to *Cyrtodonta canadensis* Billings, but is more erect, comparatively higher posteriorly, and has its outline more produced and more sharply rounded in the postero-cardinal region. *C. ventricosus* Hall, is not so wide posteriorly, and on the whole has a different outline, being, besides, more ventricose. *C. grandis* Ulrich, is a larger and almost circular shell.

Formation and locality:—Middle third of the Trenton shales, at Minneapolis, Minnesota.

CYPRICARDITES GERMANUS, n. sp. or var.

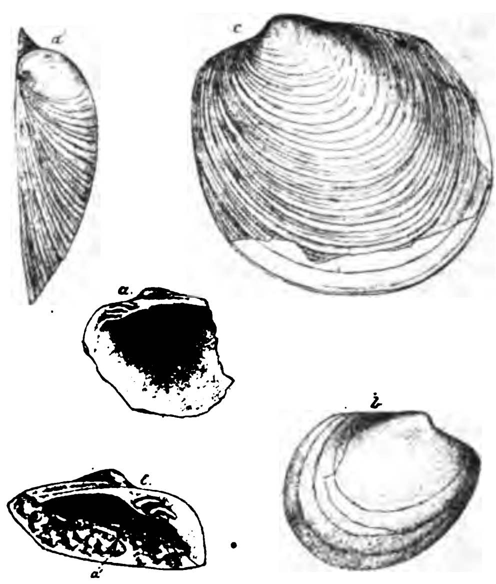

FIG. 22, *a* and *b*.

FIG. 22, *a* and *b*. *Cypricardites germanus*, nov. nom. *b*, fragment of a right valve of this species or variety, restored, nat. size; *a*, interior of same, showing the thin hinge, anterior teeth, and the faintly impressed muscular scar; *c*, *d*, and *e*, lateral and anterior views, and the greater part of the hinge of a small left valve of *Cypricardites grandis* Ulrich, from the upper Trenton near Danville, Kentucky. Introduced for comparison with *C. germanus* and *C. tenellus*.

Of this form I have several fragmentry shells, none of them better than the one above illustrated. Ordinarily, I would not consider such material as sufficient to justify description and naming, but in the present instance it has seemed right to set good custom aside. The specimens, namely, exhibit a

striking departure from usual *Cypricardites* in the great projection beyond the beaks of the anterior end of the shell. In most species the anterior end is very short,—occasionally the beaks are quite terminal—but in *C. grandis* Ulrich (Amer. Geol., vol. 6, p. 387, 1890) of which a small and unusually oblique example is illustrated in fig. 22, *c*, *d*, and *e*, it is longer than in any other species heretofore described, while in the proposed *C. germanus* the projection is comparatively greater yet.

The shell in *C. germanus* is very thin, so that even the anterior muscular impression is scarcely recognizable, the hinge too is very thin, while the anterior teeth are small and drawn out to an unusual distance in front of the beaks. Excepting that the teeth are less curved and the hinge plate less expanded where they occur, the characters of the form are not greatly different from *C. grandis*. It is very likely merely a small variety of that species. Both are found in the upper beds of the Trenton near Danville, Kentucky, the small form a few feet higher in the series than the large *C. grandis*. I have seen also a number of internal casts, in the lower part of the Galena limestone and in the shales immediately beneath them, at localities in Goodhue and Fillmore counties, Minnesota, that may belong to one or the other of these forms, but they are all too illy preserved to admit of determining their relations with certainty.

CYPRICARDITES TENELLUS, n. sp.

Fig. 23. *Cypricardites tenellus*, n. sp. *a*, right valve, with strongly marked lines of growth; *b*, hinge of same; *c*, anterior view of same; *d*, a smaller valve with finer surface markings and wider anterior end; *e*, anterior view of same; all of the natural size.

Shell of medium size or less, moderately ventricose, not very oblique, subovate, widest posteriorly, slightly alate and subangular or sharply rounded in the postero-cardinal region. Hinge line long, slightly arcuate; posterior margin straightened in the upper half, broadly rounded and produced a little in the lower half; ventral margin rather strongly convex, and most prominent a little behind the middle; anterior end more or less narrowly rounded. Beaks small, incurved, projecting moderately beyond the hinge line; situated about one-fourth of the entire length behind the anterior extremity; umbones full, prominently rounded. Cardinal slope slightly concave. Surface marked with rather fine concentric striæ, and sometimes with strong, distant lines of growth as well.

Shell substance very thin. Hinge plate almost linear when compared with the majority of the species of the genus; with two very slender posterior lateral teeth in the right valve, and probably only one in the left; anterior teeth obscure in the specimen, consisting apparently of one or two slight longitudinal folds in the margin of the shell. Muscular impressions very faint.

In this species the hingement is reduced to the minimum of strength so far noticed in the genus. It is possible that this reduction has gone beyond the just limits of *Cypricardites*, but in view of the fact that the species is approached in this respect by *C. germanus*, which, as well as several other undoubted species of the genus, as now understood, it also resembles in the general expression of its shells, it did not seem to me worthy now of greater recognition than specific.

C. cingulata, from a lower horizon in the shales, is a more ventricose shell, with the umbonal ridge stronger, and the outline a little different, being longer from the beaks to the postero-ventral margin, with both the anterior end and the hinge line shorter.

Formation and locality: - Upper third of the Trenton shales, about six miles south of Cannon Falls, Minnesota. A cast of the interior, collected by Mr. Wm. H. Scofield from the lower part of the Galena Limestone, at Wykoff, Fillmore county, probably belongs here.

CYPRICARDITES NANUS, n. sp.

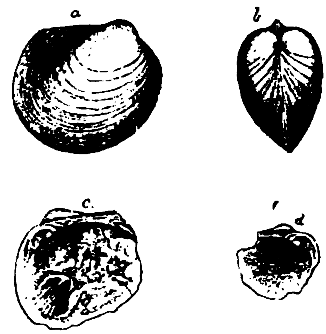

Fig. 24, *Cypricardites nanus*, n. sp. *a* and *b*, side and anterior views of a silicified specimen, nat. size; *c*, anterior part of the hinge of a small left valve; *d*, hinge of a right valve.

Shell small, ventricose, slightly oblique, the outline subcircular, a little the widest posteriorly, with the hinge line straight or very slightly arcuate, and the anterior end produced a little beyond the line of the circular curve formed by the posterior and ventral margins; height and length respectively as five is to six; postero-cardinal border subangular. Beaks small, strongly incurved, projecting well above the hinge; situated about one-fifth of the entire length from the anterior extremity; umbones full, prominent, with a strongly rounded ridge traceable from the beak nearly to the postero-ventral margin. Cardinal slope rather strongly concave. Surface marked with fine lines of growth. With age a few strong marginal wrinkles may be formed. Shells ubstance thin.

Hinge of moderate strength, considering the size of the shell, with two anterior teeth in each valve, the lower and forward one forming the sharp upper boundary of a narrow and horizontally extended muscular impression. Posterior teeth not well shown in the material at hand; probably two or three, and much like those of *C. haynianus* Safford.

This species is closely related to *C. haynianus* Safford, a common species of the Trenton of Kentucky and Tennessee, but is smaller, more ventricose, with the outline more nearly circular, the beaks less nearly terminal, the umbonal ridge stronger, and the shell thinner. It has also only two instead of three or more anterior hinge teeth. None of the other species known to me are very closely related.

A similar, though not a strictly identical species, is indicated by a cast of the interior, collected by Mr. Wm. H. Scofield, at

Wykoff, in Fillmore county of this state, where he found it at the base of the Galena limestone. This cast belonged to a larger shell than has been noticed of *C. nanus.* Its outline is also a little different, being too wide posteriorly, and more sharply curved at the postero-basal border, while the beaks are more nearly terminal. In short, the outline is more nearly like that of *C. haynianus* (see fig. 25*b*), slightly longer, perhaps, but I am satisfied that it is distinct from Safford's species, having obviously been formed by a thinner shell in which the internal ridge, which is always present in his species, was absent or, as is the case with *C. nanus*, too illy defined to leave a certain mark on the casts.

Formation and locality:—The nine, more or less defective specimens of this species contained in my cabinet, were collected from the upper beds of the Trenton, in Mercer county, Kentucky.

CYPRICARDITES HAYNIANUS (?) Safford.

Cyrtodonta haynlana SAFFORD, 1869. Geol. Tenn., pl. F., fig. 1.

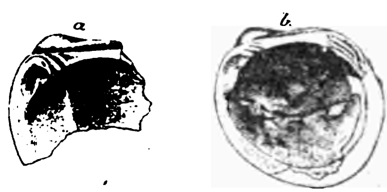

Fig. 25. *Cypricardites haynianus* Safford. Upper Trenton, near Danville, Kentucky; *a*, a well preserved fragment of a right valve, showing the anterior part of the hinge, with its teeth, the muscular impression, and the internal ridge; *b*, the interior of a smaller right valve with the anterior teeth disposed more horizontally than usual in this species.

I am nearly convinced that this species is represented in the Galena shales of Minnesota, but all of the specimens seen by me are internal casts, and none of these are sufficiently well preserved to permit an unequivocal determination of their relations. The internal ridge and the compressed beaks (they are concave on the inner side) required by casts positively known to belong to the species, are determinable in some of the specimens, but each of these is either incomplete or has suffered compression in the shales, so that the original shape of the shells is left in doubt. Under the circumstances I thought it well to call the attention of Minnesota collectors to the forms, in the hope that some of them may find better specimens.

Among some lamellibranch shells received from Mr. Wm. H. Scofield, there is a fragment of a *Cypricardites* that he obtained

from the upper third of the Trenton shales, at the locality six miles south of Cannon Falls that has furnished so many interesting shells of this class. This specimen consists of the anterior third of the shell itself, showing about half of the hinge with three anterior teeth and a muscular impression beneath them. Every point that is preserved corresponds so nearly with fig. 25 *a*, that it would surprise me greatly if it turned out to be distinct from *C. haynianus*.

MATHERIA RUGOSA, n. sp.

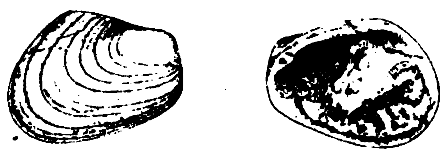

Fig. 26, *Matheria rugosa*, n. sp External and internal views of the only specimen seen, nat. size. The posterior part of the hinge is broken away and that portion of the figures is to be regarded as a restoration.

Shell large for the genus, trapezoidal, widest posteriorly, with the beaks nearly terminal, small, incurved, projecting slightly above the hinge; a strongly convex umbonal ridge. Anterior end descending abruptly from the beaks, below rounding sharply into the nearly straight ventral border; posterior margin produced and strongly rounded in the lower half, obliquely subtruncate above and probably forming an obtuse angle at the junction with the hinge line; the latter very gently arched. Surface marked with strong, concentric wrinkles, and finer lines of growth. Shell substance of moderate thickness.

Hinge plate strong, flat, slightly arcuate, the upper half of the width, posterior to the beaks, finely striated lengthwise. Cardinal teeth small, situated just beneath the beaks, directed toward the postero-basal margin, with one in the right valve and, on each side of it, a deep socket for the reception of the two teeth of the left valve. Anterior muscular scar rather distinct, subcircular, situated immediately beneath the teeth. Posterior extremity of hinge wanting in the specimen, probably without teeth.

This species is almost certainly a true *Matheria*, a genus described by Billings for a single species occuring in the Trenton rocks of Canada and Kentucky, and which he called *M. tener*.*

*Can. Nat. and Geol., vol. 3, p. 440, 1858.

Several other species, as yet undescribed, are known to me from the same rocks in Kentucky, but all are smaller and less wide posteriorly. *M. tenera* has the dorsal and ventral margins nearly parallel.

Formation and locality:—Upper third of the Trenton shales, six miles south of Cannon Falls, Minnesota.

ISCHYRODONTA OVALIS, n. sp.

FIG. 27. *Ischyrodonta ovalis*, n. sp. *a*, and *b*, external and internal views of a right valve; *c*, and *d*, anterior and cardinal views of the same: nat. size.

Shell small, moderately ventricose, almost regularly elliptical in outline, with the greatest width and thickness midway between the ends; width and length about as two is to three. Beaks small, situated near the anterior extremity, compressed by a flattening of the surface which, expanding, extends over the greater part of the ventral slope. Edges of valves meeting at the center of the ventral margin, apparently gaping a little at the ends. Umbonal ridge prominently rounded, cardinal slope abrupt, very little concave. Surface marked with strong lines of growth and a few finer concentric striae, both inclining to be irregular.

Hinge plate arcuate, widening posterior to the beaks, grooved as for the reception of an internal ligament. Cardinal teeth two, projecting downward and backward from the hinge plate, which is thin at this point, and supported by an internal process that seems to extend up into the cavity of the beak, and projects on each side of the teeth so as to give the whole the appearance of a quadrifid tooth. Anterior muscular scar rather small, occupying the anterior extremity of the shell.

This species is not strictly congeneric with the types of *Ischyrodonta* (Amer. Geol., vol. 6, pp. 173-175), but there is no other established genus known to me offering a closer agree

ment, and before I can consider the erection of a new genus as fully justified, I wish to see the main peculiarties of the shell confirmed in other species. The uncertainty of the position of the species is increased by the fact that it might be referred, with equal propriety perhaps, to the genus *Matheria*, of Billings. I infer therefore that we are dealing with an undescribed generic type having somewhat intermediate relations between *Matheria* and *Ischyrodonta.*

Formation and locality:—At present known only from Richmond, Indiana, where it was found in the upper beds of the Cincinnati group. Equivalent strata are exposed in the vicinity of Spring Valley, Minnesota.

PLETHOCARDIA, n. gen.

(*Pletho*, to be full; *kardia*, heart, in allusion to the shape of the closed valves.)

Shell thin, inequilateral, oblique, tumid, with the margins closed; beaks large, prominent, spirally enrolled, and curving forward. Cardinal margin, posterior to the beaks, with a narrow, but deep escutcheon or lunette. A strong and large, bifid, cardinal tooth projects forward and downward from the thin edge of the straight hinge plate; one strong linear, lateral tooth, or thickened internal cartilage support, beneath the posterior extremity of the hinge line, and close to the margin. Anterior muscular scar strongly impressed, situated in the antero-dorsal angle, margined on the inner side by a curved ridge extending from the under side of the cardinal tooth. In casts of the interior the filling of the anterior impressions forms a small but sharply defined lobe. Posterior muscular scars and pallial line unknown. Type: *P. umbonata*, n. sp.

The shells of this genus present considerable external resemblance to those of *Whitella*, Ulrich. As a rule they will probably prove shorter, more erect and comparatively more ventricose. I believe also that *Whitella* offers closer affinities than any other genus yet known, and I can see that it may prove difficult in some cases to distinguish species of the two genera, when the internal characters are not available. Of course, such difficulties cannot obtain when the diagnostic characters of the hinge are preserved, since the strong cardinal tooth of *Plethocardia* is too marked a feature to be overlooked in comparing the twc genera. Good casts of the interior even are easily distinguished by the presence of the small lobe beneath and in front of the beaks of *Plethocardia*, the muscular impressions being very much less distinct in the casts of *Whitella*. In the

posterior part of the hinge, however, the two genera are practically the same.

It is possible that this genus represents an early type of those heavy and otherwise peculiar shells which Zittel has embraced in his family *Megalodontidæ.* A general resemblance is to be noted yet I doubt very much that any true relationship existed between them.

PLETHOCARDIA UMBONATA, n. sp.

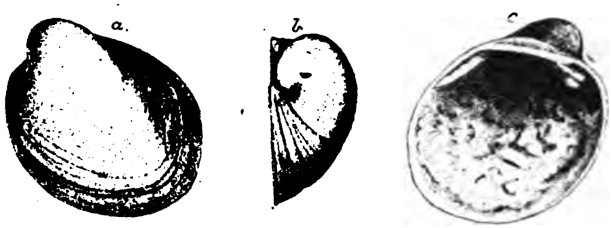

Fig. 28. *Plethocardia umbonata*, n. sp. *a* and *b*, lateral and anterior views of a left valve; c, inner side of same, showing the escutcheon, the bifid cardinal tooth, anterior muscular impression, and the internal ridge-like thickening of the shell just within the postero-dorsal border; natural size.

Shell rather small, moderately oblique, strongly ventricose, widest posteriorly, subovate in a side view. Beaks large, very prominent, inrolled; umbonal ridge angular, traceable to the postero-basal margin. Cardinal slope narrow, rather sharply defined, concave. Anterior end very short, nearly vertical, rather sharply rounded above; dorsal margin arcuate, graduating into the posterior curve; the latter is produced slightly in the lower part and quickened as it turns into the broadly convex ventral margin. Surface marked with concentric lines of growth, some of them strong.

Escutcheon narrow, extending backward from the beaks nearly to the posterior extremity of the hinge. Cardinal tooth large, bifid, projecting obliquely forward from the lower side of the hinge line. A strong, ridge-like thickening of the shell, probably representing the support of an internal ligament, occurs just within the postero-cardinal margin. Anterior muscular scar situated in a cup-like depression formed by a curved ridge which proceeds from the underside of the cardinal tooth, and the antero-cardinal margin of the shell.

It is possible that this species is not distinct from the *Cyrtodonta cordiformis* of Billings. His figures of that species look so much like the Minnesota shell above described that I am nearly satisfied that they must be congeneric at least. It might be a

Whitella but it is not a true *Cypricardites*. Compared with *P. umbonata* it appears that in the Canadian shell the beaks are situated farther back from the anterior extremity, the umbonal ridge is rounded instead of angular and the outline different, especially that of the posterior end, which is also wider.

Formation and locality:—Upper third of the Trenton shales, six miles south of Cannon Falls, Minnesota. Collected by Wm. H. Scofield.

PLETHOCARDIA SUBERECTA, n. sp.

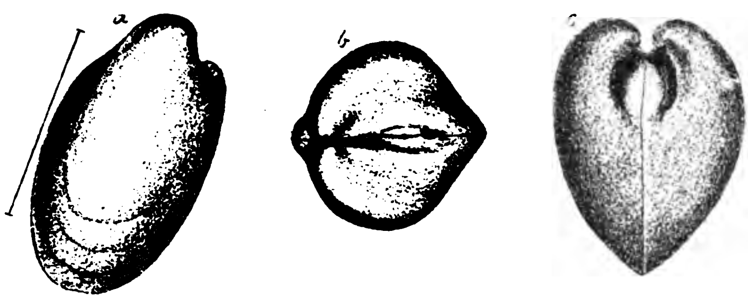

Fig. 29. *Plethocardia suberecta*, n. sp. *a*, *b*, and *c* lateral, dorsal, and anterior views of a cast of the interior; natural size.

Shell small, but little oblique, exceedingly ventricose, short, subelliptical in a side view, with the dorso-ventral diameter much the longest. Beaks very prominent, large, strongly incurved, nearly terminal, umbonal ridge strong, sharply rounded, with the cardinal and posterior slopes very abrupt, and nearly flat. Anterior end very short, the part in front of the beaks of casts consisting chiefly of the sharply defined, lobe-like filling of the anterior muscular impressions. Anterior and posterior margins gently convex, subparallel; ventral edge sharply rounded. Hinge line short, scarcely extending posterior to the umbonal ridge, as seen in a side view. In the casts there is a depression beneath the beaks that is prolonged on each side around the muscular scar. The escutcheon seems to have been narrow, but the internal ligament supports at the posterior end of the hinge line have left two strong grooves, one on each side.

This species, though clearly congeneric with *P. umbonata*, is so readily distinguished from that species that comparisons are unnecessary,

Formation and locality:—Galena shales, near Cannon Falls, Minnesota.

WHITELLA PRÆCIPTA Ulrich.

Whitella præcipta ULRICH, 1890. The American Geologist, vol. vi, p. 386.

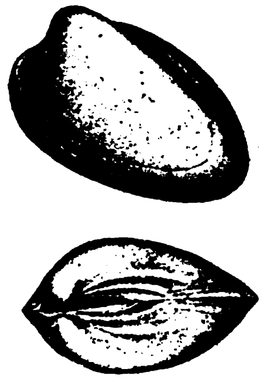

Fig. 30, *Whitella præcipta* Ulrich. Lateral and cardinal views of a cast of the interior; nat. size.

Shell of medium size, ventricose, very oblique, elongate-ovate, or subrhomboidal in a side view, produced and sharply rounded in the postero-basal region. Beaks of moderate size, prominent, strongly incurved, umbones full; umbonal ridge well marked, traceable almost to the posterior extremity. Anterior end small, very short, narrowly rounded; ventral margin gently convex; posterior end produced and narrowly rounded in the lower part; from the point of greatest extension to the posterior side of the projecting umbones, the outline is gently and almost uniformly convex. Hinge line comparatively short, its length less than half the length of the shell, the edge inflected to form a distinct escutcheon, extending somewhat in front of the beaks. In casts of the interior the internal cartilage supports have left distinct impressions of unusual width, on each side and behind the impression produced by the escutcheon. A low and obscurely defined ridge is also to be seen running through the middle of the cardinal slope. Anterior muscular scar faint, subovate, acuminate below, situated very near the anterior extremity. Pallial line represented by a thin raised line, running near and parallel with the margin of the cast. It can be traced from the anterior scar to the impressions of the internal ligament supports.

This species is very similar to *W. obliquata* Ulrich, from the upper beds of the Cincinnati group, yet I do not doubt that they are really quite distinct species. That species grows to a larger size, is less elongate, wider posteriorly, with the beaks

and umbones smaller, and the anterior end larger. The impressions of the internal ligament supports also are very much less distinct.

Formation and locality:—Galena shales, near Cannon Falls, Minnesota.

WHITELLA CONCENTRICA, n. sp.

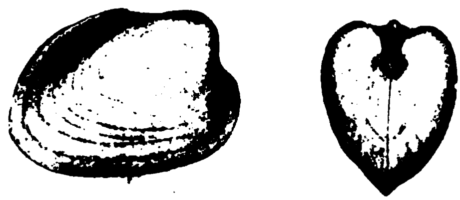

Fig. 31, *Whitella concentrica*, n. sp. Lateral and anterior views of a cast of the interior, nat. size. The beak of the left valve has been restored.

Shell rather beneath the medium size, oblique, ventricose, widest posteriorly, trapezoidal; beaks large, prominent, in curved; umbones full, with a sharply rounded ridge or line of gibbosity extending backward from the beaks to the posterior extremity of the shell. Anterior end short, narrowly rounded; ventral edge very gently convex; posterior end produced and sharply rounded in the lower half, more gently convex and sloping forward rapidly above, merging gradually into the curve of the dorsal side. Cardinal and posterior slopes slightly concave. Hinge line about half as long as the shell, with the edge inflected so as to form a narrow escutcheon, extending but little if at all in front of the beaks. Internal ligament supports leave a distinct impression on each side of the postero-cardinal margin in casts of the interior. Anterior muscular scars dis tinct though faintly impressed, situated in the antero-dorsal angle. Surface of casts, especially in the lower and posterior parts, marked with fairly distinct, rounded, concentric folds.

The concentric marks of growth are stronger in this species than in any other known to me. It is shorter than *W. præcipta* more ventricose than *W. compressa*, and has much fuller um bones than *W. obliquata*.

Formation and locality:—Middle third of the Trenton shales, at Minneapolis, Minnesota

CUNEAMYA SULCODORSATA, n. sp.

Fig. 32. *Cuneamya sulcodorsata*, n. sp. Lateral and anterior views of the type specimen, nat. size.

Shell small, moderately convex, oblong, subquadrate, with the dorsal and ventral margins subparallel and gently convex, the posterior end truncate, very slightly produced and sharply rounded, almost angular at the base; anterior end very short, narrowly rounded. Beaks subterminal, full, decumbent, strongly incurved, projecting forward rather than upward; umbonal ridge moderately prominent, not angular. Dorsal slope with a distinct, expanding sulcus; ventral and anterior slopes gently and uniformly convex. Hinge line posterior to the beaks long, the edge inflected so as to form a well-marked escutcheon. In front of and beneath the beaks a deep lunule. Surface marked with regular, concentric folds, obsolete on the cardinal slopes, and by two or three times more numerous fine striæ, which seem to have extended over all parts of the surface.

This neat shell, though seeming to be a true species of *Cuneamya*, cannot be confounded with any species of the genus so far described.

Formation and locality:—At the top of the Hudson River group, Spring Valley, Minnesota.

PUBLICATIONS OF THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

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THE SECOND ANNUAL REPORT, FOR 1873. 145 pp., 8vo.; with illustrations. By *N. H. Winchell* and *S. F. Peckham*. Published in the Regents' Report for 1873. Out of print.

THE THIRD ANNUAL REPORT FOR 1874. 42 pp., 8vo.; with two county maps. By *N. H. Winchell*. Published in the Regents' Report for 1874. Out of print

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THE THIRTEENTH ANNUAL REPORT, FOR 1884. 196 pp Geological reconnoisances, the Vermilion iron ores, the crystalline rocks of Minnesota and of the Northwest, the Humboldt salt-well in Kittson county, records of various deep wells in the state, fossils from the red quartzyte at Pipestone, reports on the New Orleans Exposition and on the General Museum, by *N. H. Winchell;* Geology of Minnehaha County, Dakota, by *Warren Upham;* Chemical report, by *Prof. Jas. A. Dodge;* Minnesota geographical names derived from the Dakota language, by *Prof. A. W. Williamson;* insects injurious to the cabbage, by *O. W. Oestlund;* Geological notes in Blue Earth county, by *Prof. A. F. Bechdolt;* and on a fossil elephant from Stockton, by *Prof. John Holzinger;* papers on the Cretaceous fossils in the boulder clays in the Northwest, by *George M. Dawson* and by *Woodward* and *Thomas;* and notes on the Mammals of Big Stone lake and vicinity, by *C. L. Herrick.*

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THE FIFTEENTH ANNUAL REPORT FOR 1886. 493 pp.; 8vo.; 120 diagram illustrations and sketches in the text, and two colored maps; embracing reports on observations on the crystalline rocks in the northeastern part of the state, by *Alexander Winchell*, *N. H. Winchell* and *H. V. Winchell*; Chemical report by *Prof. J. A. Dodge*; additional railroad elevations by *N. H. Winchell*; list of Minnesota geographical names derived from the Chippewa language, by *Rev. J. A. Gilfillan*, and notes on Illæni, describing three new species, by *Aug. F. Foerste.* Also as supplement II of the Regents Report for 1887-1888.

THE SIXTEENTH ANNUAL REPORT FOR 1887. 504 pp., 8vo.; two plates and 83 other illustrations. Contains reports on the original Huronian area, the Marquette iron region, on the Gogebic and Penokee iron-bearing rocks, on the formations of northeastern Minnesota (including the physical aspects, vegetation, quadrupeds and other vertebrates), the geology of the region northwest from Vermilion lake to Rainy lake and of the Little and Big Fork rivers; also notes on the Molluscan fauna of Minnesota.

THE SEVENTEENTH ANNUAL REPORT FOR 1888. pp., 280; 8vo.; ten text illustrations. Contains: Report of *N. H. Winchell*; the crystalline rocks of Minnesota, a general report of progress made in the study of their field relations, with a bibliography of recent works on the crystalline rocks; report of *H. V. Winchell*, field observations in the iron regions; report of *Uly. S. Grant*, geological observations in northeastern Minnesota.

THE EIGHTEENTH ANNUAL REPORT FOR 1889. Report of further field observations in the regions of the crystalline rocks of the state and in the area of the original Huronian, by *N. H. Winchell*, and a review of American opinion on the older rocks, by *Alexander Winchell.* Octavo, pp. 234.

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No. 7. The Mammals of Minnesota. *C. L. Herrick*. In press.

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